PB-214 407

REMOTE SENSING STUDY OF THERMAL DISCHARGES TO LAKE MICHIGAN. ILLINOIS-INDIANA-MICHIGAN

National Field Investigations Center

Prepared for:

Environmental Protection Agency

October 1972

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

PB 214 407

REMOTE SENSING STUDY OF THERMAL DISCHARGES TO LAKE MICHIGAN

ILLINOIS-INDIANA-MICHIGAN

NATIONAL TECHNICAL INFORMATION SERVICE

NATIONAL FIELD INVESTIGATIONS CENTER-DENVER
DENVER, COLORADO
AND
REGION V, CHICAGO, ILLINOIS

OCTOBER 1972

CLEAN WATER

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT

REMOTE SENSING STUDY

OF

THERMAL DISCHARGES

TO

LAKE MICHIGAN

ILLINOIS - INDIANA - MICHIGAN

Details of illustrations in
this document may be better
studied on microfiche.

National Field Investigations Center
Denver, Colorado
and
Region V
Chicago, Illinois

October 1972

I-a

TABLE OF CONTENTS

Chapter		Page
	TABLE OF CONTENTS	i
	LIST OF FIGURES	iii
I	SUMMARY AND CONCLUSIONS	1
II	INTRODUCTION	3
III	RESULTS OF THERMAL DATA ANALYSIS	7
	17 OCTOBER 1972 FLIGHT	7
	1. Northern Indiana Public Service - Michigan City Power Plant	7
	2. Northern Indiana Public Service - Bailly Power Plant	7
	3. Industrial Thermal Discharges	7
	4. Industrial Thermal Discharges	8
	5. Northern Indiana Public Service - Mitchell Power Plant	8
	6. Industrial Thermal Discharges	8
	7. Commonwealth Edison Company - State Line Power Plant	9
	8. Industrial Thermal Discharges	9
	9. Commonwealth Edison Company - Waukegan Power Plant	9
	19 OCTOBER 1972 FLIGHT	9
	1. Michigan Consumers Power Company - Palisades Power Plant	10
	2. Northern Indiana Public Service - Michigan City Power Plant	11
	3. Northern Indiana Public Service - Bailly Power Plant	11

4. Industrial Thermal Discharges 12

5. Northern Indiana Public Service -
Mitchell Power Plant 12

6. Thermal Discharges -
Union Carbide and American Oil Companies . . 12

7. Thermal Discharges - Inland Steel and
Youngstown Sheet and Tube Companies 13

8. Commonwealth Edison -
State Line Power Plant 13

9. Industrial Thermal Discharges 13

10. Industrial Thermal Discharges 14

11. Commonwealth Edison -
Waukegan Power Plant 14

LIST OF FIGURES

Number		Following Page
1	Northern Indiana Public Service - Michigan City Power Plant	7
2	Northern Indiana Public Service - Bailly Power Plant	7
3	Northern Indiana Public Service - Mitchell Power Plant	8
4	Commonwealth Edison Company - State Line Power Plant	8
5	Industrial Thermal Discharges	8
6	Industrial Thermal Discharges	9
7	Commonwealth Edison Company - Waukegan Power Plant	9
8	Michigan Consumers Power Company - Palisades Power Plant	10
9	Northern Indiana Public Service - Michigan City Power Plant	11
10	Northern Indiana Public Service - Bailly Power Plant	11
11	Northern Indiana Public Service - Mitchell Power Plant	12
12	Industrial Thermal Discharges	13
13	Industrial Thermal Discharges	13
14	Industrial Thermal Discharges	13
15	Commonwealth Edison - Waukegan Power Plant	14
16	Thermal Map Trace	14

I. SUMMARY AND CONCLUSION

An aerial reconnaissance study was conducted along the shoreline of Lake Michigan from South Haven, Michigan in a clockwise manner through Waukegan, Illinois. The flights were carried out during the afternoon hours on 17 October 1972 and 19 October 1972.

A total of six power plants were in operation during the course of this study. Thermal data, obtained at a distance of 1,000 feet from the respective discharge position along shore, for the MCPC - Palisades Power Plant and the CEC Waukegan Power Plant are presented as follows:

Power Plant	Surface Temperature Increase over Lake Michigan Background at 1,000 feet from Discharge on 19 October 1972.
Palisades	14.3°F (12.2°F at 2,000 feet)
Waukegan	16.1°F (3.4°F at 2,000 feet)

The 1,000 feet value stems from the Recommendation No. 1 adopted by the Third Session of the Lake Michigan Enforcement Conference. This recommendation reads:

> "Applicable to all waste heat discharges except as noted above:(*) At any time, and at a maximum distance of 1,000 feet from a fixed point adjacent to the discharge, (agreed upon by the State and Federal regulatory agencies), the receiving water temperature shall not be more than 3°F above the existing natural temperature nor shall the maximum temperature exceed those listed below whichever is lower."

The maximum "surface to three-foot depth" temperature recommended for October is 65°F. The Palisades Power Plant was also in violation of this 65°F temperature value at the 1,000 feet point.

---

*Municipal waste and water treatment plants, and vessels.

Violations could not be ascertained for the remaining four power plants due to the lack of adequate surface water temperature data. On 19 October 1972, the CEC State Line Power Plant was not covered due to low level clouds in the immediate area.

Numerous violations of Recommendation No. 3 were recorded (during both flights) in Gary/Calumet, Indiana, Calumet Harbor, Illinois and Waukegan, Illinois areas. This recommendation reads as

> "Discharge shall be such that geographic areas affected by thermal plumes do not overlap or intersect. Plumes shall not affect fish spawning and nursery areas nor touch the lake bottom."

From the data given in this report, it must be concluded that Recommendations No. 1 and No. 3 of the Lake Michigan Enforcement Conference are not being fulfilled by many sources of thermal and industrial discharges within the Conference area.

II. INTRODUCTION

An aerial remote sensing study of the thermal discharges to Lake Michigan was conducted on the following dates:

1) 17 October 1972, 1400-1530 hours CDT

2) 19 October 1972, 1500-1630 hours CDT

This effort was requested by the Enforcement Division, Region V, EPA. The study area included waters affected by discharges from electric power plants and industrial sites from South Haven, Michigan to Waukegan, Illinois. The power plants covered were

..Michigan Consumers Power Company - Palisades Power Plant

..Northern Indiana Public Service - Michigan City Power Plant

..Northern Indiana Public Service - Mitchell Power Plant

..Commonwealth Edison - State Line Power Plant

..Commonwealth Edison - Waukegan Power Plant

The location of each power station is shown on the map which appears at the back of this report. Each industrial discharge will be identified herein by company to the extent possible and geographical location.

The thermal data were recorded by an infrared line scanner (IRLS) on board a USAF RF-4C (Phantom) aircraft. Two such aircraft were utilized during this study. The temperature resolution of this scanner is 0.1° Centigrade.

The IRLS will record only surface temperatures in water. Water is opaque to this region of the intermediate infrared band. The

maximum depth penetration in either fresh or salt water is 0.01 cm. Therefore, a submerged thermal discharge can be detected from an aircraft with an infrared line scanner only if all or part of the warm wastewater reaches the surface of the receiving body of water.

The thermal data were recorded on 5-inch film in the form of a thermal map. At the time of flight, ground truth, in the form of surface water temperatures, was obtained for each power station location. The cooling water discharge temperatures and, in some cases, background water surface temperatures of Lake Michigan, were provided by EPA, Region V. These temperature values served as an absolute reference for the calibration, and subsequent analysis of the airborne thermal data, especially for the surface waters 1,000 feet distant from the respective points of thermal discharges. The accuracy placed upon these temperatures values as given in this report, is $\pm$1°Fahrenheit. Once the calibration described above has been effected, this accuracy becomes a relative number which is not dependent upon or a function of any particular temperature value within the established temperature limits. This accuracy does not include the respective accuracies of the terrestrial instrumentation used by the ground truth personnel to obtain the Lake Michigan surface water and discharge temperatures. These values would, to a good approximation, add to the $\pm$ 1°F given above to form a total accuracy for a given temperature value presented.

The approximate scale of the thermal maps is as follows:

1) 17 October 1972 flight - 1:32,435

2) 19 October 1972 flight - 1:29,600

These values were obtained from the original negatives.

The first EPA flight, carried out in Lake Michigan, occurred on 14 September 1972. The results of that study were presented at the Fourth Session of the Lake Michigan Enforcement Conference held in late September 1972. The purpose of the September Study was to document the extent of the thermal discharges from electric power plants into Lake Michigan from Muskegon, Michigan along shore in a clockwise direction to Twin Creeks, Wisconsin. The study revealed violations of Recommendations No. 1 and No. 3 adopted by the Third Session of the aforementioned Conference. These recommendations read as follows:

Recommendation No. 1

> "Applicable to all waste heat discharges except as noted above:(*) At any time, and at a maximum distance of 1,000 feet from a fixed point adjacent to the discharge, (agreed upon by the State and Federal regulatory agencies), the receiving water temperature shall not be more than 3°F above the existing natural temperature nor shall the maximum temperature exceed those listed below whichever is lower."

The maximum "surface to three-foot depth" temperature recommended for September is 80°F.

Recommendation No. 3

> "Discharge shall be such that geographic areas affected by thermal plumes do not overlap or intersect. Plumes shall not affect fish spawning and nursery areas nor touch the lake bottom."

---

*Municipal waste and water treatment plants, and vessels.

The purpose of the October study, which is the contents of this report, was to further document the violations of the above-mentioned recommendations by thermal discharges in the area from South Haven, Michigan (Palisades Power Plant) along shore clockwise to Waukegan, Illinois (Waukegan Power Plant). For the month of October, the maximum "surface to three-feet-depth" temperature, of Recommendation No. 1, is 65°F.

It is worthy to note that the accuracy of the instrumentation used to measure the surface water temperatures in Lake Michigan, by ground personnel, has been given as 0.1°Centigrade.

III. RESULTS OF THERMAL DATA ANALYSIS

All data interpretations and analyses were carried out on the original negative from the infrared line scanner. Results of the thermal analyses for each respective thermal discharge are presented as follows:

A. 17 OCTOBER 1972 FLIGHT

No ground truth was obtained for this flight. The U. S. Weather Service at Chicago O'Hare Field stated that the wind velocity at the time of flight was from the northwest at 8 to 10 mph. Each of the industrial or power plant discharges are discussed qualitatively only, due to the lack of surface water temperatures.

1. Northern Indiana Public Service - Michigan City Power Plant

   a) The plant's discharge and the resultant thermal plume are shown in the center of Figure 1. The plume measured 2,850 feet in length along shoreline to the west and 1,230 feet in width with respect to the shoreline. It was dispersing in a westerly direction.

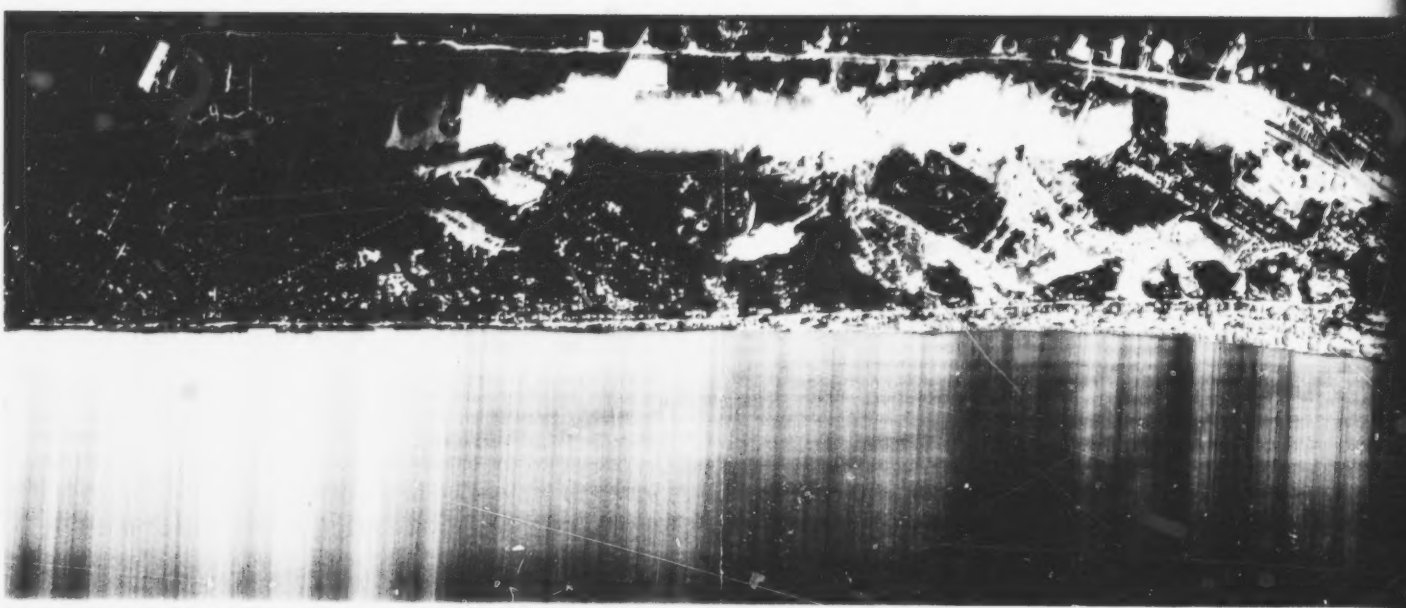
2. Northern Indiana Public Service - Bailly Power Plant

   a) The plant's thermal discharge and resultant plume are shown in Figure 2. The length and width of the plume were 4,050 feet and 1,000 feet respectively. The plume was dispersing along the breakwater to the west of the discharge.

3. Industrial Thermal Discharges

   a) In the eastern-most rectangular slip, as indicated in the center of Figure 2, a large thermal discharge was recorded.

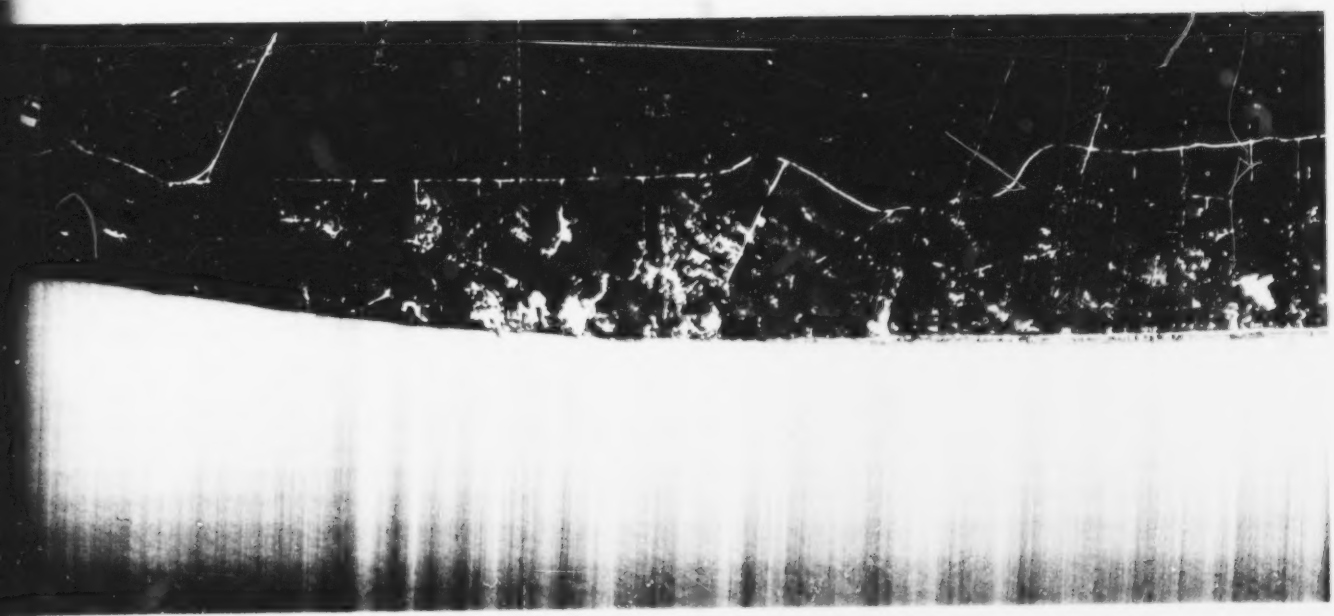
A



NORTH

8

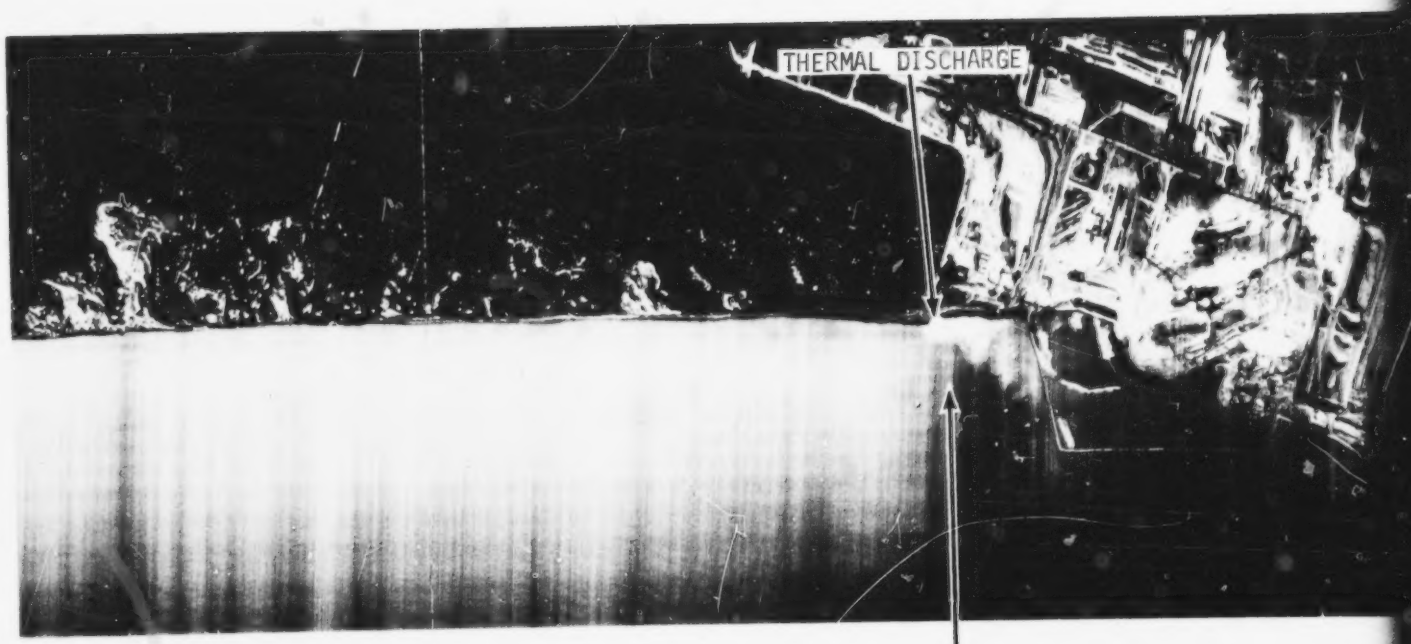
NORTHERN I
Mich



NORTHERN INDIANA PUBLIC SERVICE -
Michigan City Power Plant

FIGURE 1

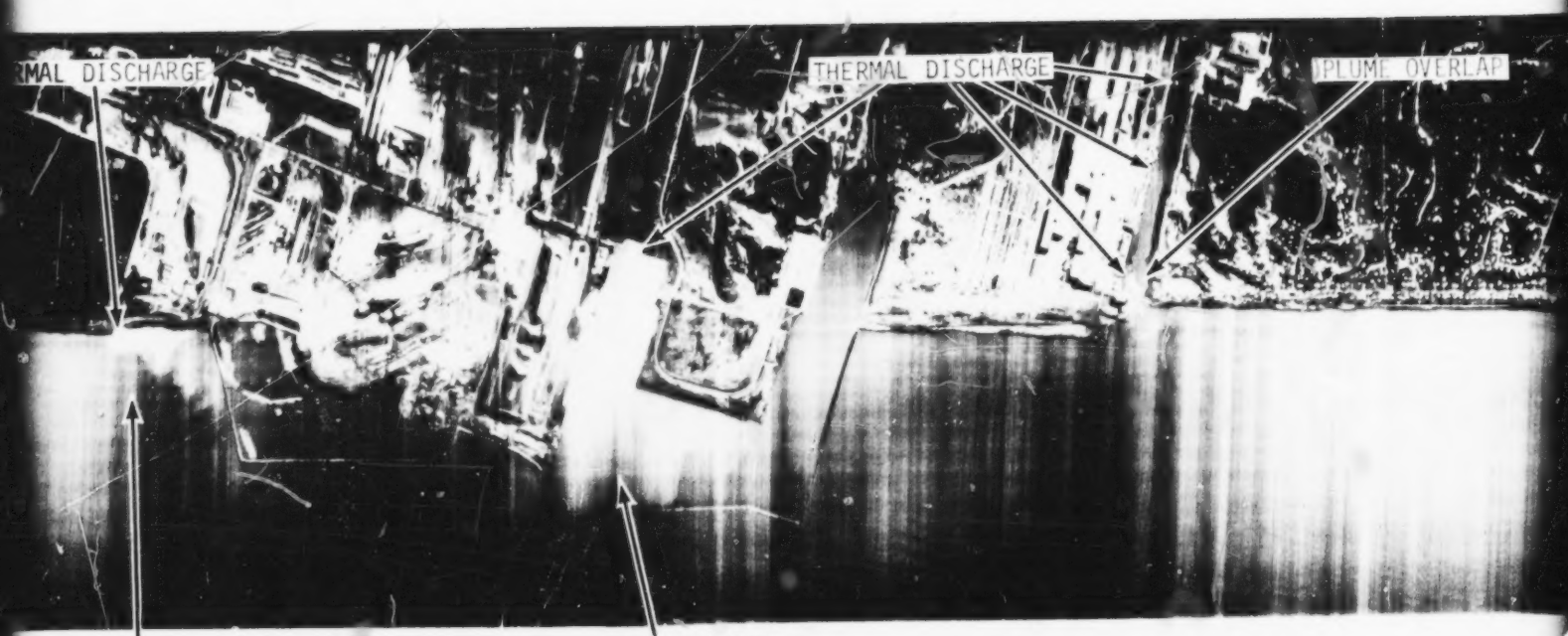
A



NORTH

NORTHERN INDIANA PUBLIC SERVICE -
Bailly Power Plant

13



ORTHERN INDIANA PUBLIC SERVICE -
Bailly Power Plant

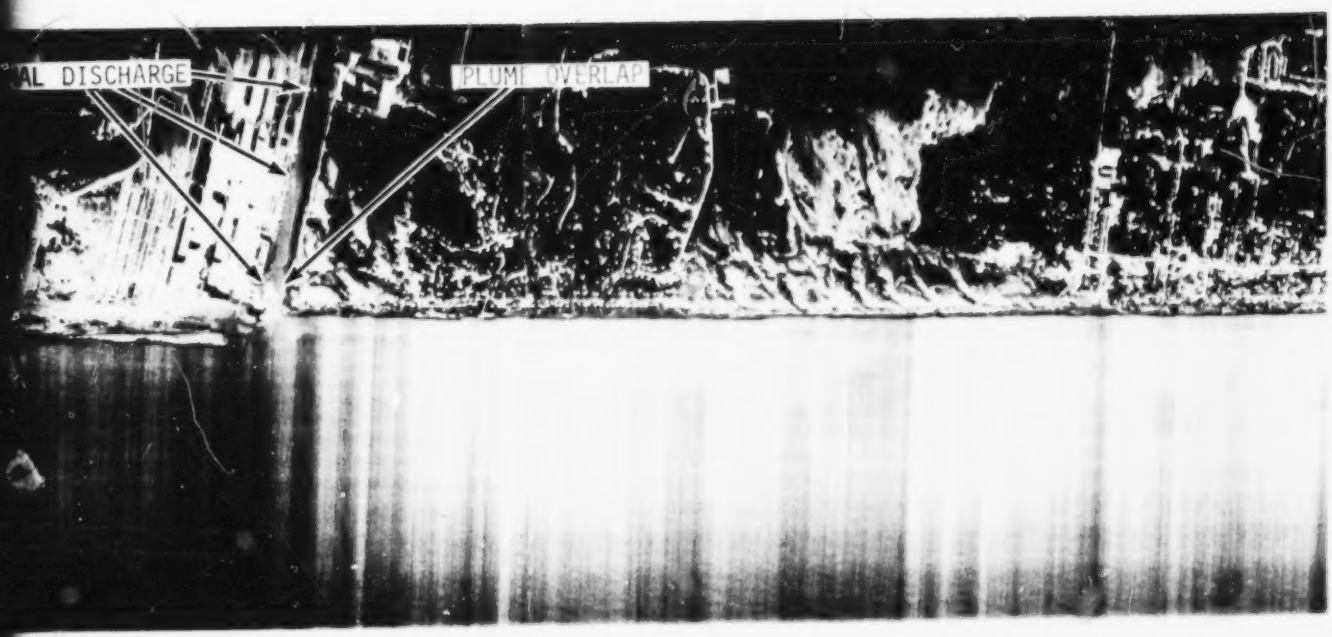


FIGURE 2

Reproduced from
best available copy.

It is seen that the hot water filled most of the area behind the breakwater. The identity of the company producing the discharge is unknown.

b) Three thermal discharges are indicated in the canal located to the west of the rectangular slips in Figure 2. The identity of the company producing the discharge is unknown.

4. Industrial Thermal Discharges

a) A total of five thermal discharges, from industrial sources, are shown in Figure 3. The eastern-most three and western-most two reportedly originate from within the facilities of the U.S. Steel Corporation. The western-most thermal plumes do intersect each other which is in violation of Recommendation 3 adopted by the Third Session of the Lake Michigan Enforcement Conference.

5. Northern Indiana Public Service - Mitchell Power Plant

a) The plant's thermal discharge and resultant plume are indicated in Figure 3. The length of the plume measured approximately 3,370 feet and extended 1,070 from shore into Lake Michigan. The plume was dispersing in an easterly direction along shore.

6. Industrial Thermal Discharges

a) The thermal discharges from

° Inland Steel Company

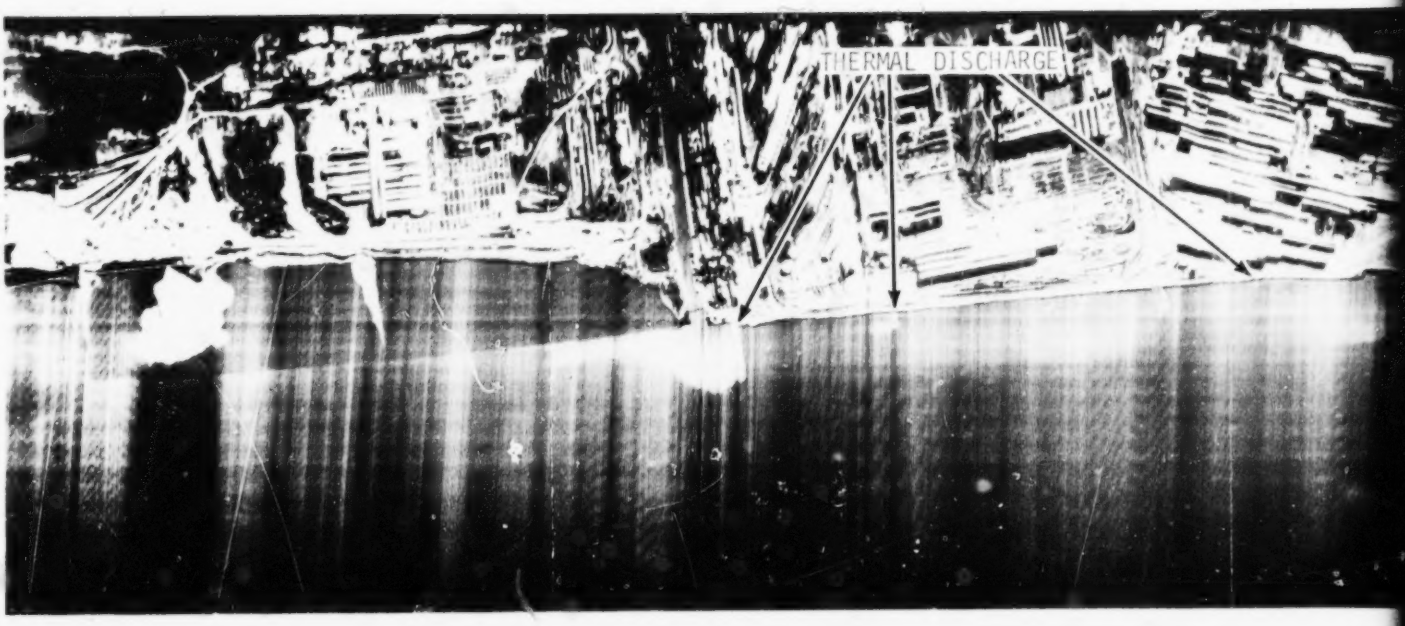
° Union Carbide Company

° Youngstown Sheet and Tube Company

° American Oil Company

are indicated in Figures 4 and 5. The respective thermal plumes were overlapping each other. The overlap is also indicated in the aforementioned figures.

A



NORTH

NORTHERN INDIA
Mitchel

B

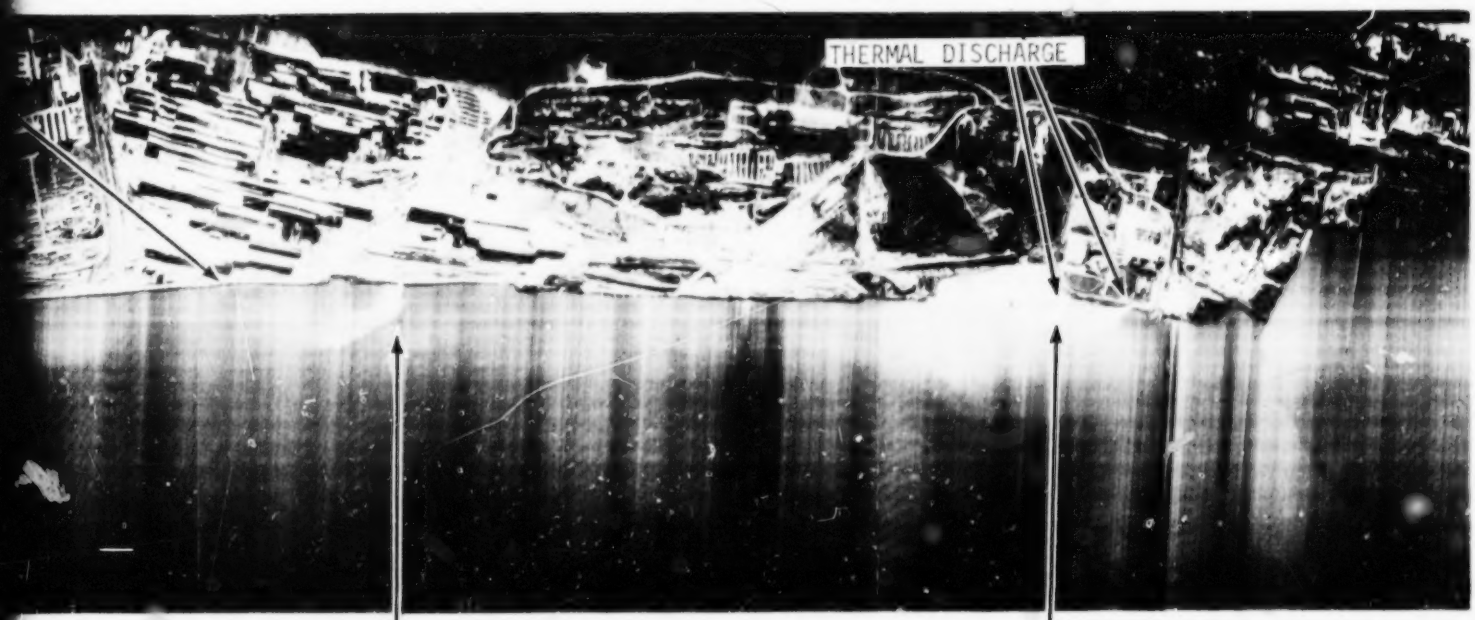

THERMAL DISCHARGE
PLUME OVERLAP
NORTHERN INDIANA PUBLIC SERVICE -
Mitchell Power Plant

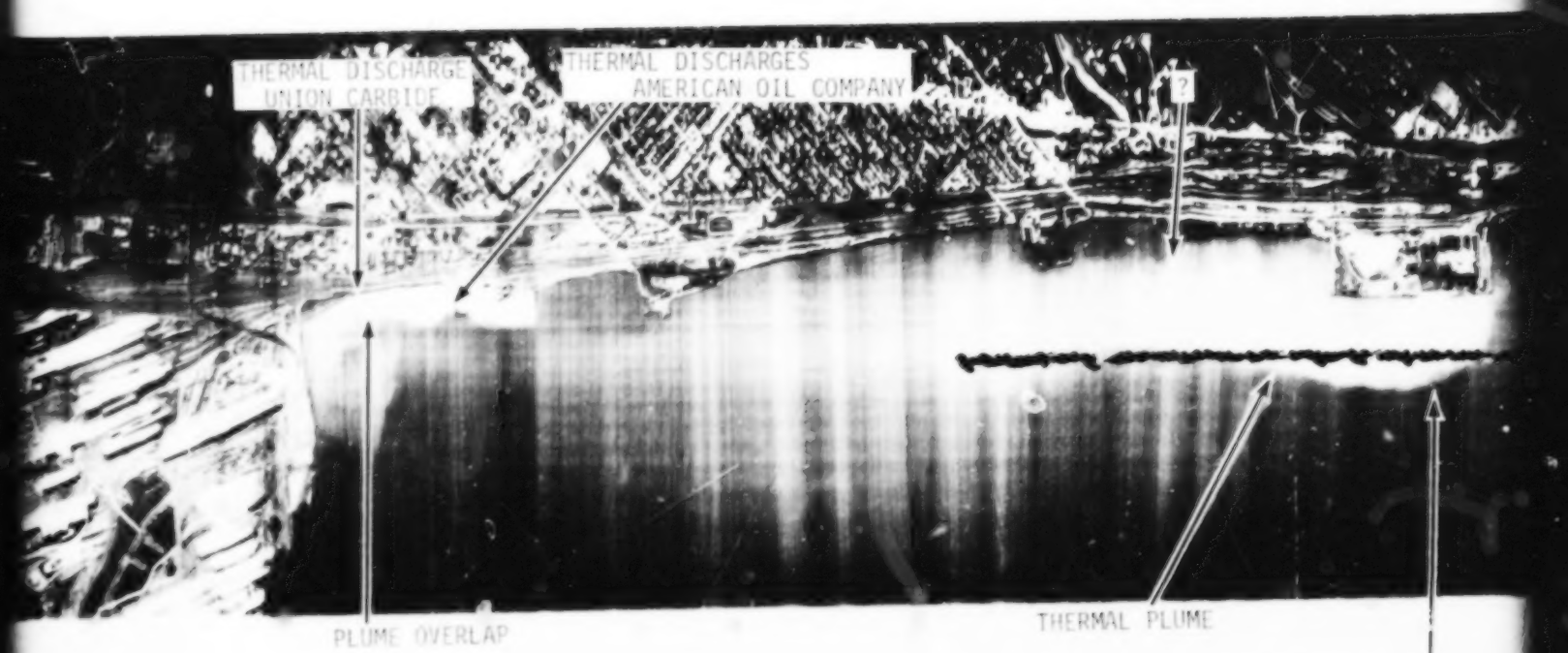
FIGURE 3

A

THERMAL DISCHARGE
UNION CARBIDE
THERMAL DISCHAR
AMERICAN O
PLUME OVERLAP
NORTH

12

B


THERMAL DISCHARGE
UNION CARBIDE
THERMAL DISCHARGES
AMERICAN OIL COMPANY
PLUME OVERLAP
THERMAL PLUME
COMMONWEALTH EDISON -
State Line P

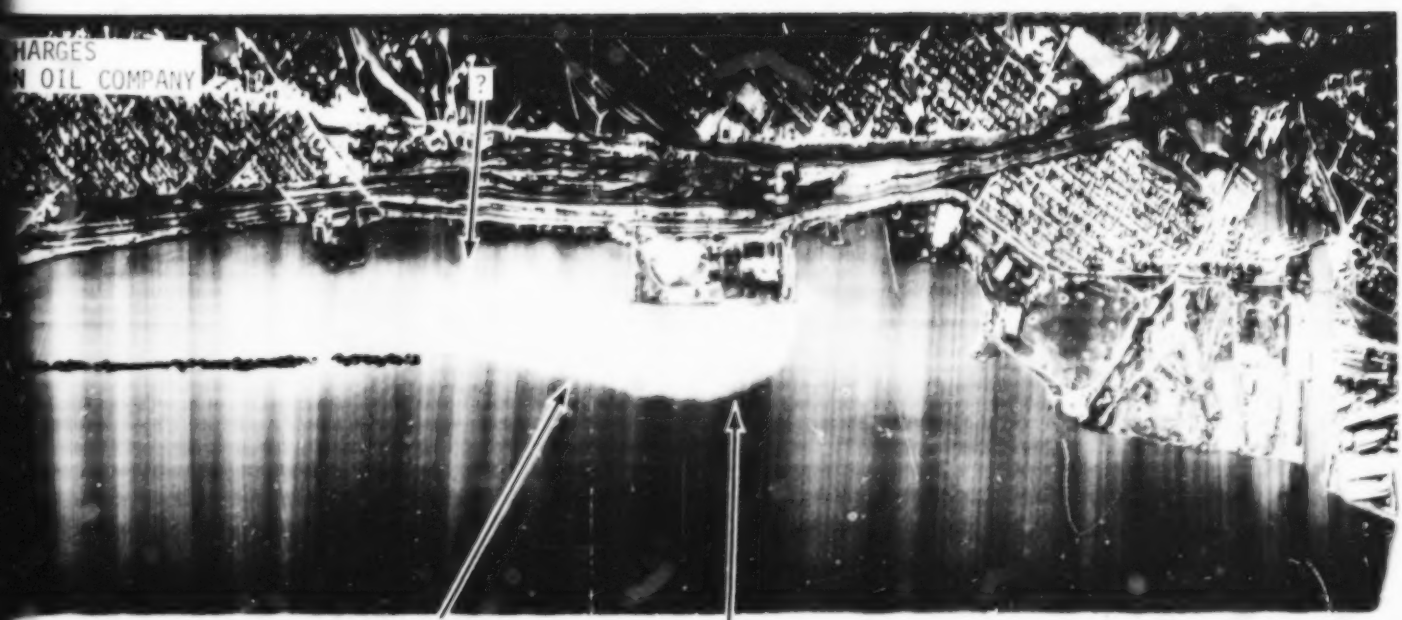
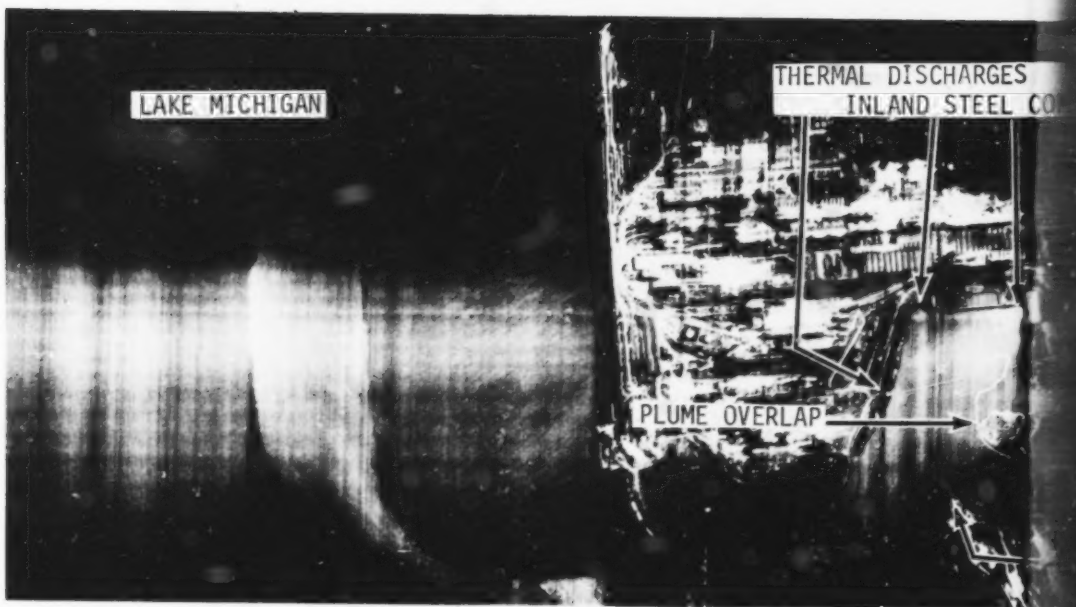


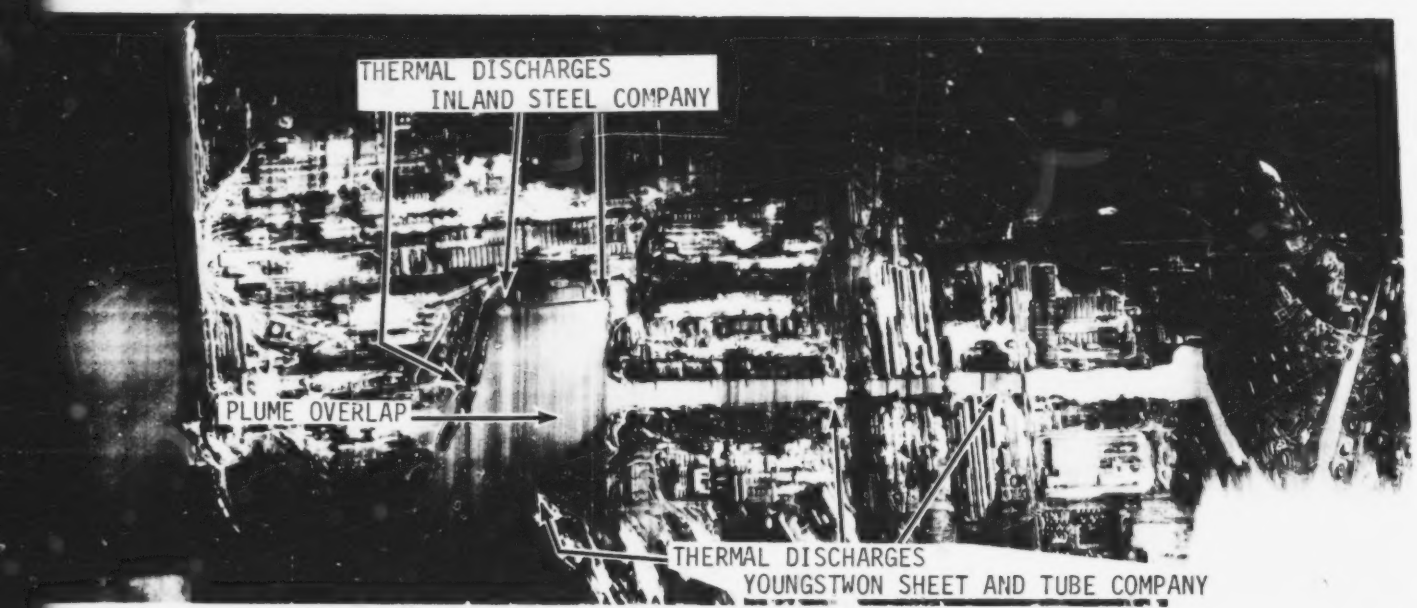
FIGURE 4

Reproduced from
best available copy.

A


LAKE MICHIGAN
THERMAL DISCHARGES
INLAND STEEL CO
PLUME OVERLAP

NORTH



INDUSTRIAL THERMAL DISCHARGE FIGURE 5

7. Commonwealth Edison Company - State Line Power Plant

   a) The thermal discharge and the resultant thermal plume from the State Line Power Plant are shown in Figures 4 and 6. The plume measured 10,900 feet in length and 1,550 feet from the discharges into Lake Michigan. This plume was being perturbed at the point, in Figures 4 and 6, indicated by the question mark. The cause is unknown.

8. Industrial Thermal Discharges

   a) A total of four thermal discharges, reportedly from industrial sources, are shown in Figure 6. The resultant thermal plumes did overlap again in violation of the aforementioned Recommendation 3.

   b) Three industrial thermal discharges are also depicted in the left center of Figure 7. These plumes were not overlapping each other.

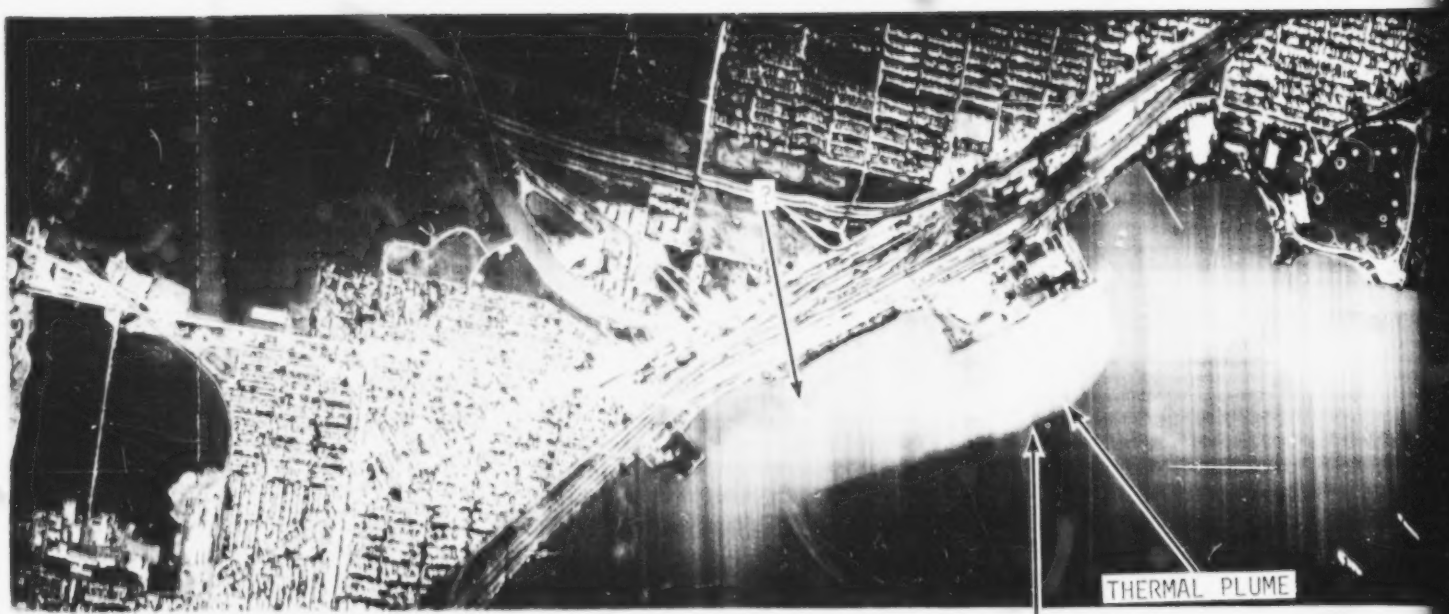
9. Commonwealth Edison Company - Waukegan Power Plant

   a) The thermal discharge and resultant thermal plume from the Waukegan Power Plant are shown in Figure 7. The plume measured approximately 11,740 feet in length and extended 2,370 feet from shore into Lake Michigan. It was dispersing along shore in a southerly direction.

B. 19 OCTOBER 1972 FLIGHT

During this flight, a limited amount of ground truth, in the form of surface water temperatures in the background waters of Lake Michigan and within the surface area of the respective thermal plumes, was obtained by EPA, Region V. Quantitative thermal data will be given in this section to the extent practicable. The

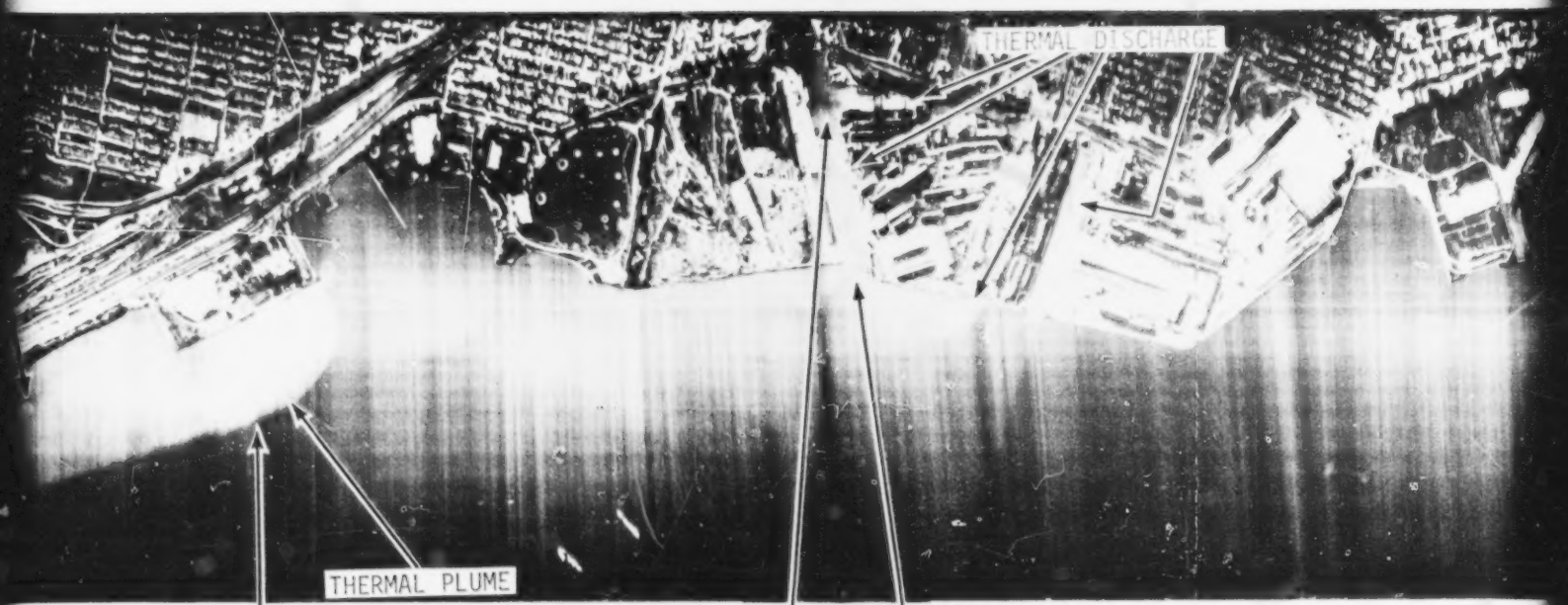
A



COMMONWEALTH EDISON -
State Line Power Plant

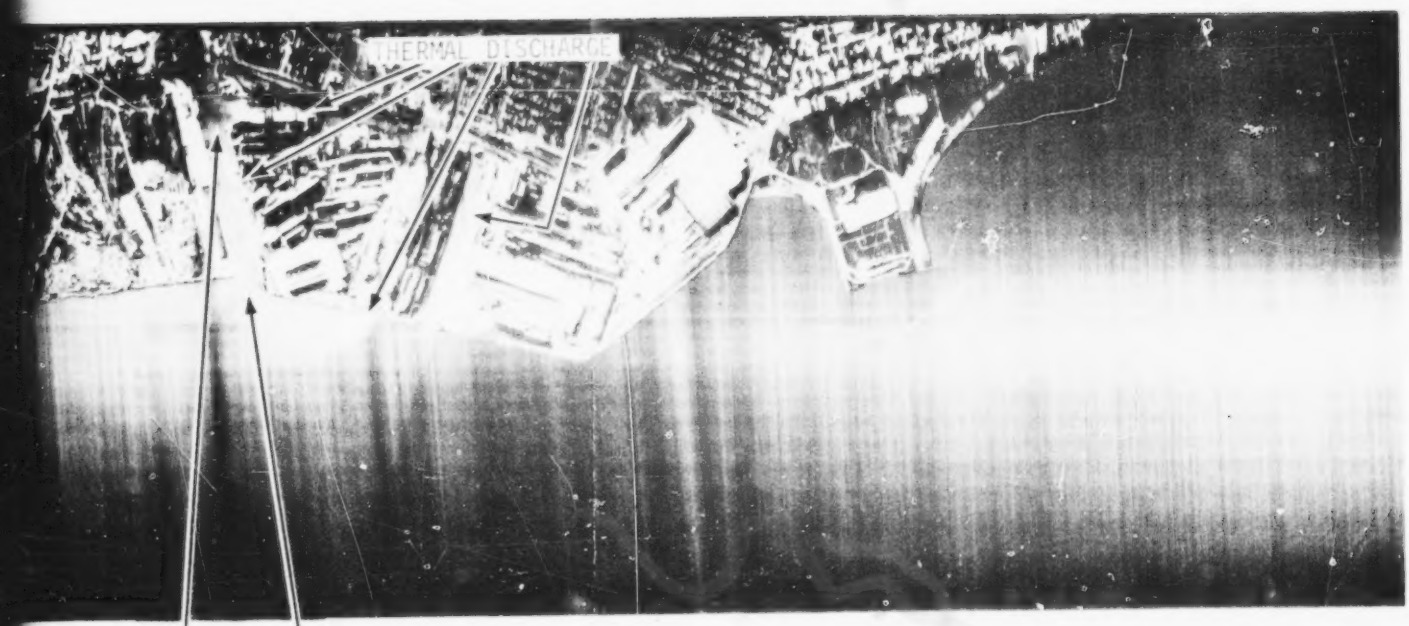
NORTH

B



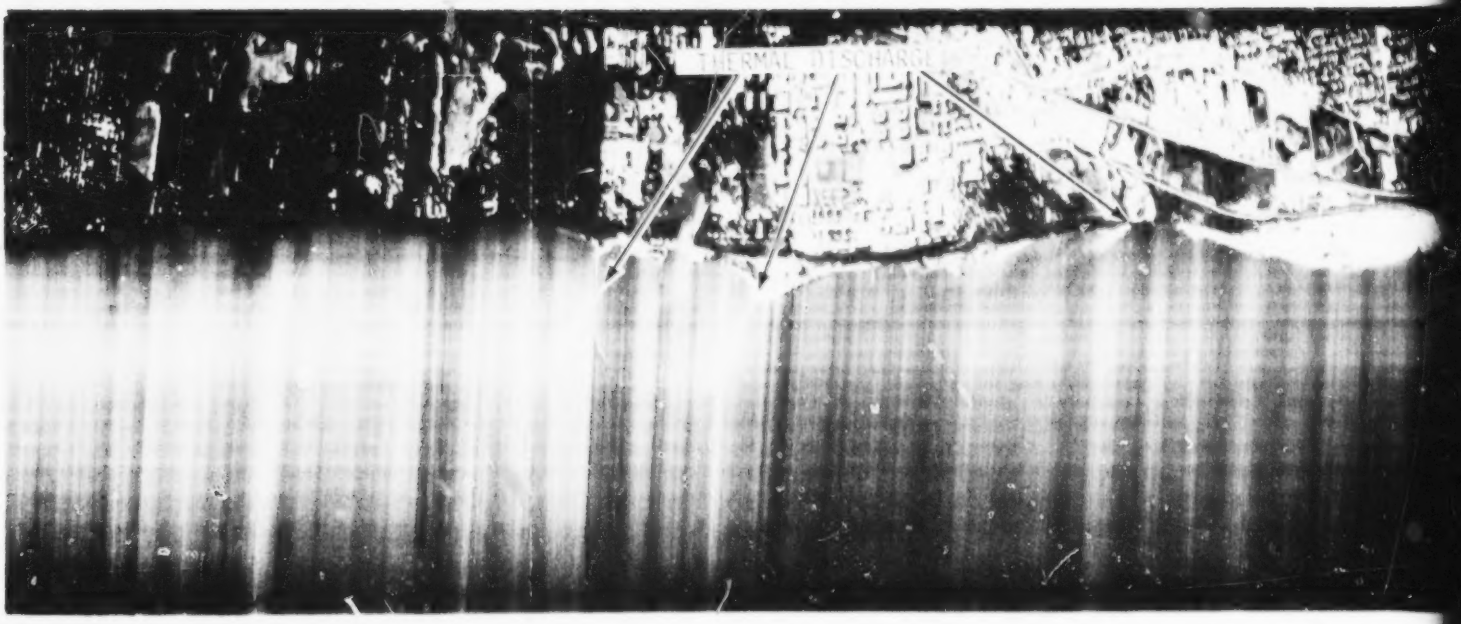
COMMONWEALTH EDISON -
State Line Power Plant

INDUSTRIAL THERM



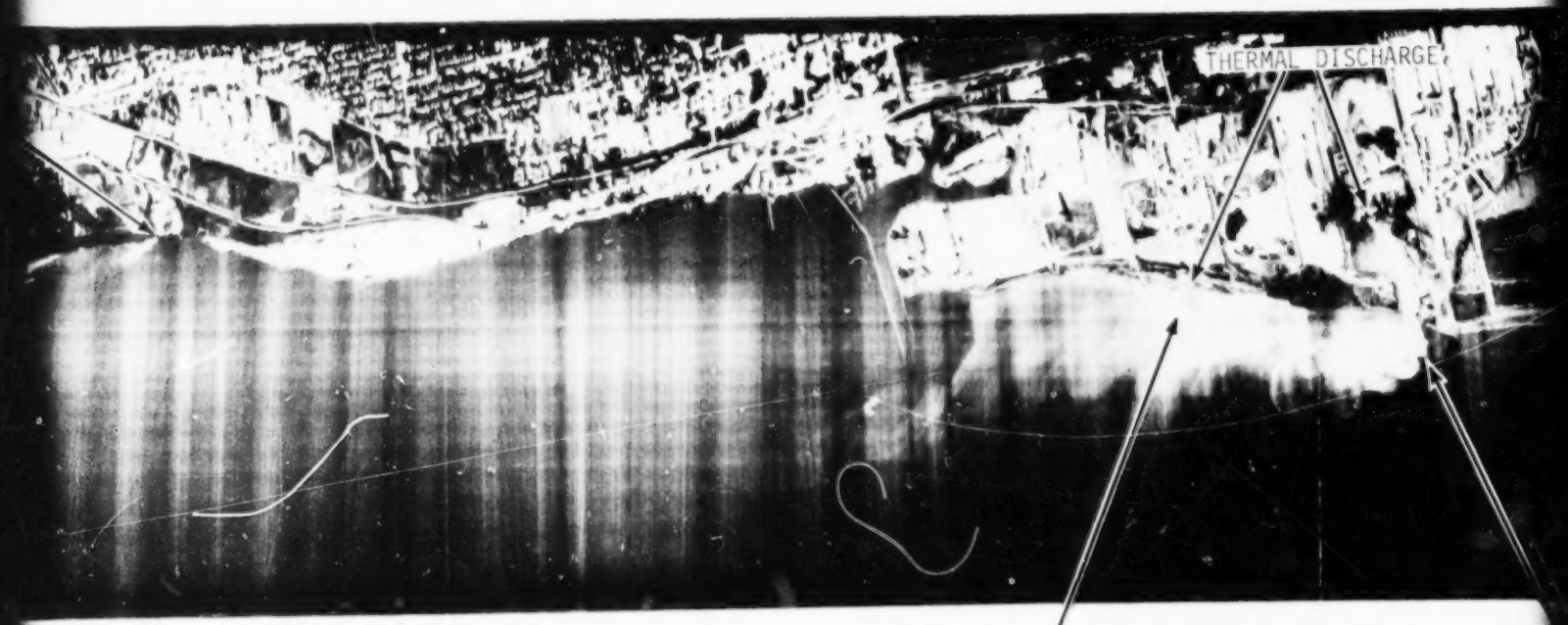
INDUSTRIAL THERMAL DISCHARGE FIGURE 6

A

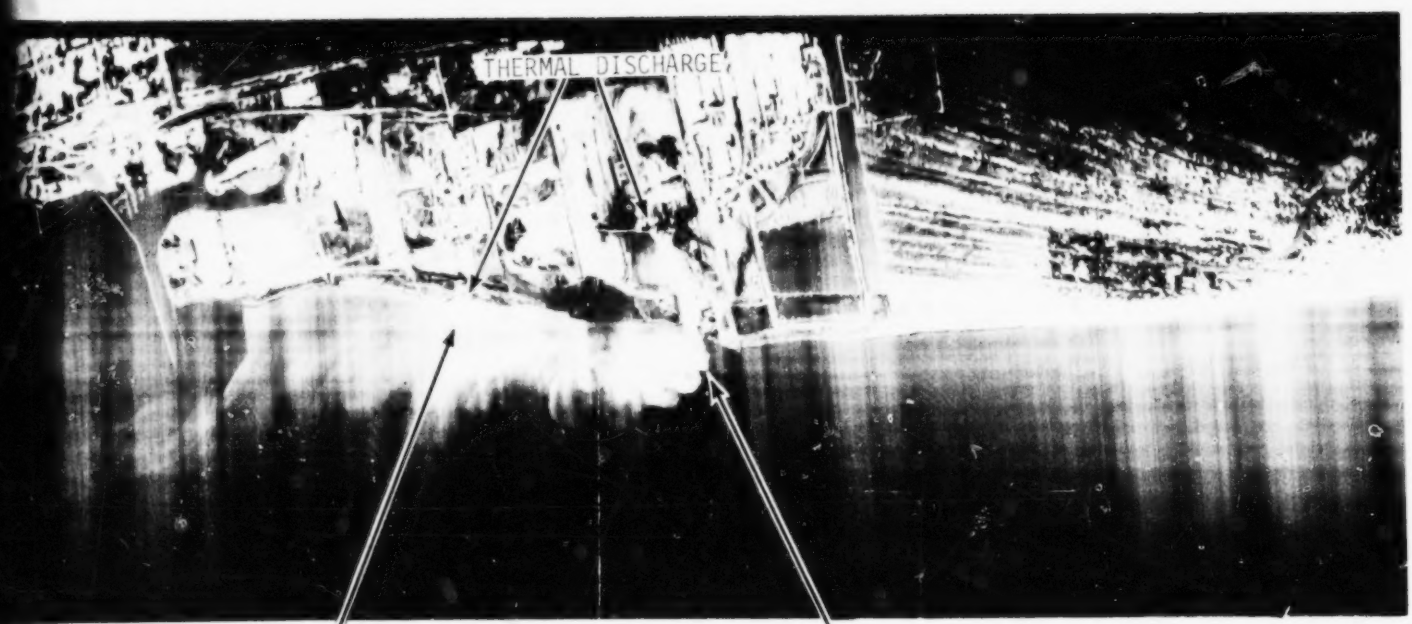


NORTH

B



CO
W



COMMONWEALTH EDISON -
Waukegan Power Plant

FIGURE 7

thermal discharges recorded during this flight are presented in the following sections:

1. Michigan Consumers Power Company - Palisades Power Plant

   a) The temperature of the discharge water was 67.6°F as provided by ground truth.

   b) The surface temperature of the background waters of Lake Michigan was 51.3°F as provided by ground truth. This temperature was obtained 3,830 feet north of the discharge and 400 feet, 1,000 feet, 2,000 feet into the Lake from shore.

   c) The thermal plume is shown in Figure 8. The surface temperature of the plume, at the 1,000 feet and 2,000 feet points shown in Figure 8, was 65.6°F and 63.5°F respectively at the time of flight. The temperature increase of the water within the plume, at the above mentioned points, was 14.3°F and 12.2°F respectively.

   d) The plant's discharge flow rate was 406,000 gallons per minute (gpm) at the time of flight.

   e) The wind velocity was from the west northwest at 8 mph.

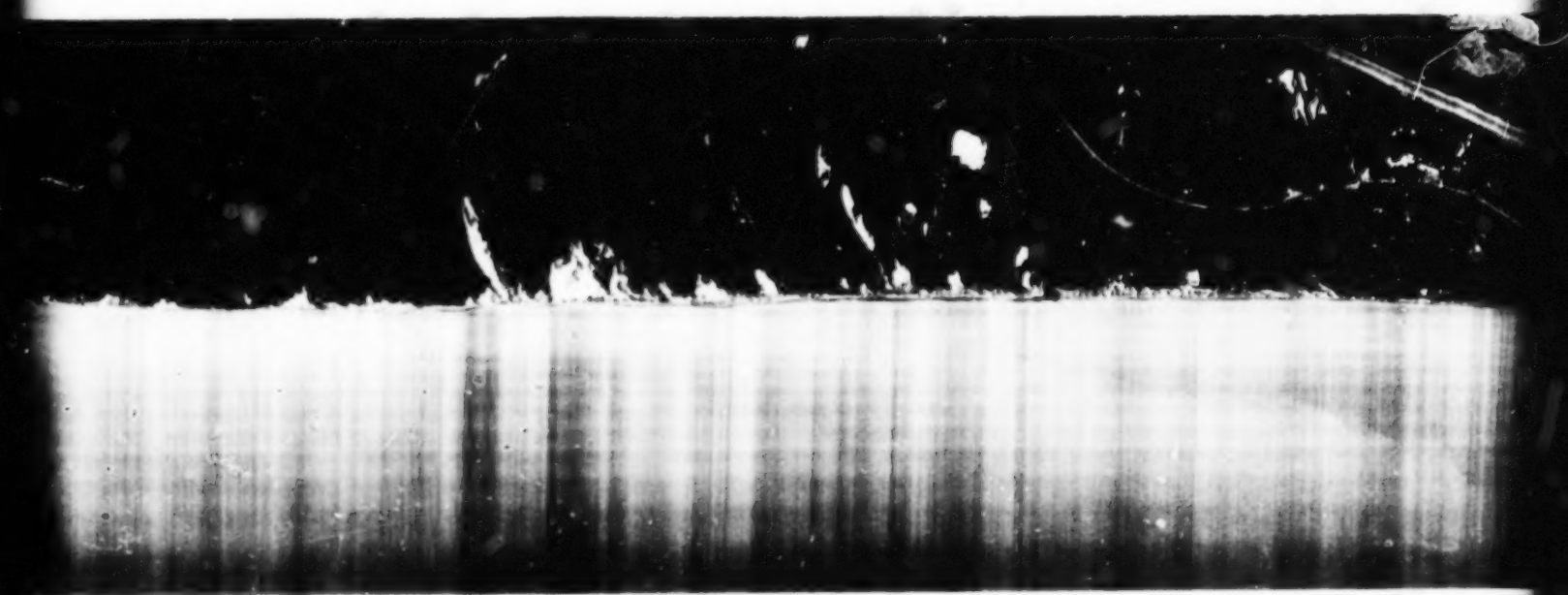
   f) The ambient surface current, measured 1,000 feet into the Lake from the discharge was 0.1 meters/sec.

   g) The accuracy of the ground equipment used to measure the surface water temperatures, was 0.1°C.

   h) The plume could be easily traced 3 miles from the discharge.

NORTH
1,000 feet

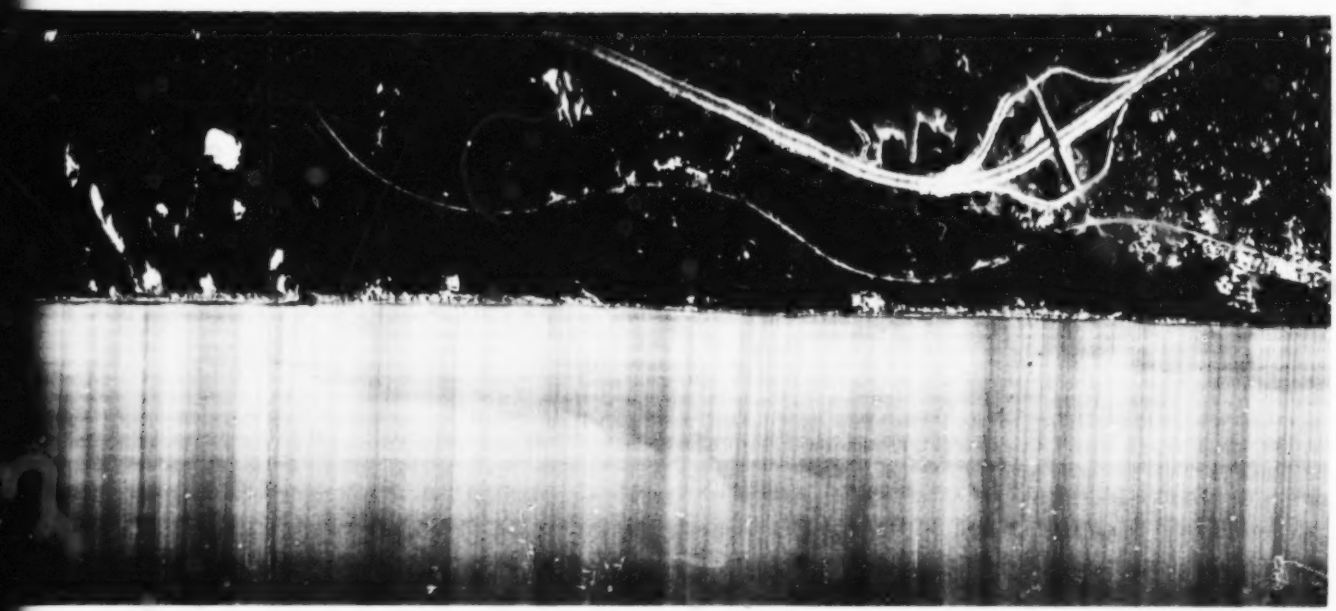
B



MICHIGAN CONSUMERS POWER COMPANY
Palisades Power Plant

15

Reproduc
best ava



MICHIGAN CONSUMERS POWER COMPANY -
Palisades Power Plant

FIGURE 8

Reproduced from
best available copy.

2. Northern Indiana Public Service - Michigan City Power Plant

a) The ground truth was obtained approximately 1 hour 50 minutes before the aircraft recorded the plant's thermal discharge. At 1335 CDT the temperature of the discharge water was measured to be 56.3°F. The surface temperature of the water in the Trail Creek Channel which is 1,500 feet east of the discharge near the end of the western-most breakwater, was 54.5°F. The thermal discharge is found in Figure 9.

b) If the respective temperatures at the time of flight were identical to those measured 1 hour 50 minutes before then the surface temperatures of the 1,000 feet and 2,000 feet points would be 55.6°F and 56.1°F. No ground truth temperatures were obtained from the background waters of Lake Michigan. Therefore, the temperature differences between the aforementioned points within the plume and the background waters cannot be provided.

c) The plume measured 4,680 feet in the east-west direction and 1,980 feet into Lake Michigan from the point of discharge.

d) The wind was from the west northwest at 3 to 8 mph.

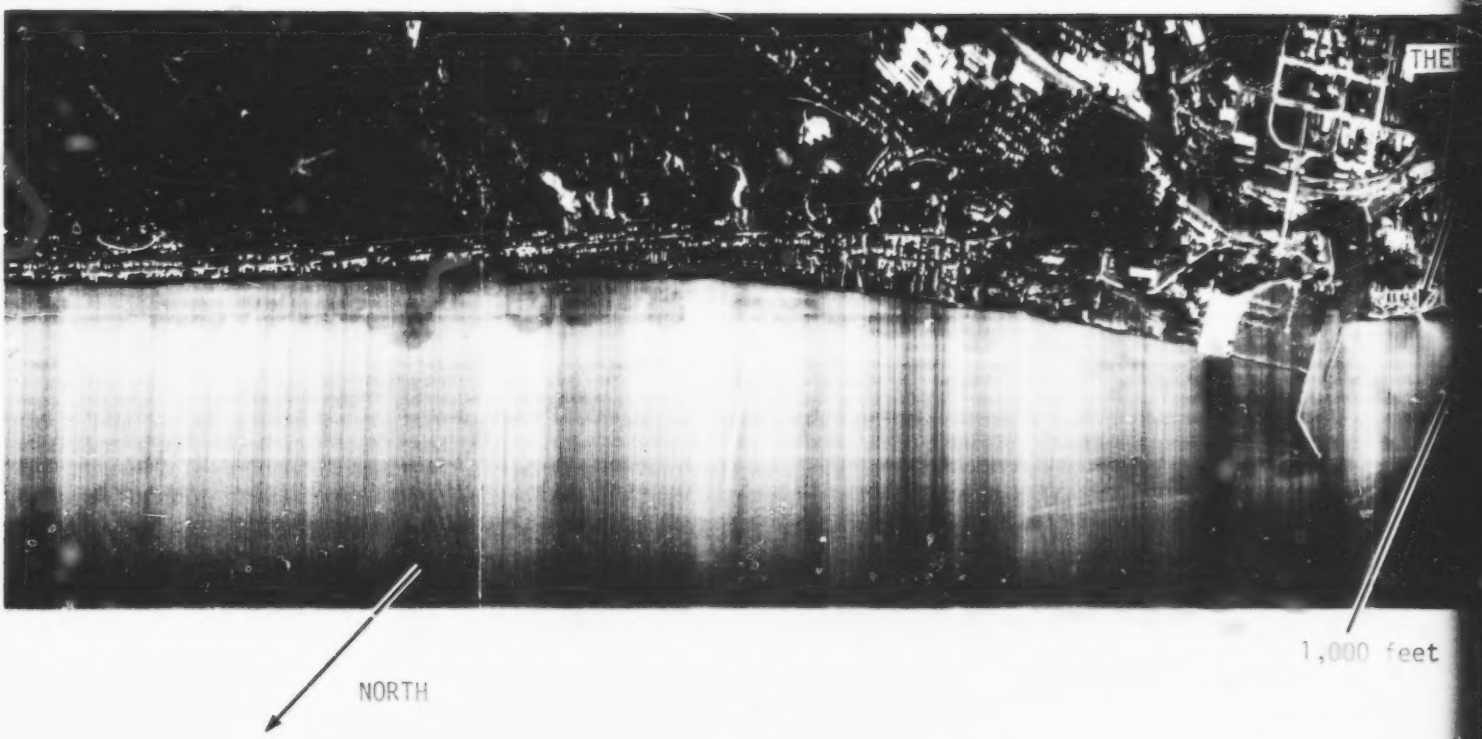
3. Northern Indiana Public Service - Bailly Power Plant

a) No ground truth was obtained for this respective thermal plume. No quantitative temperature data can be provided.

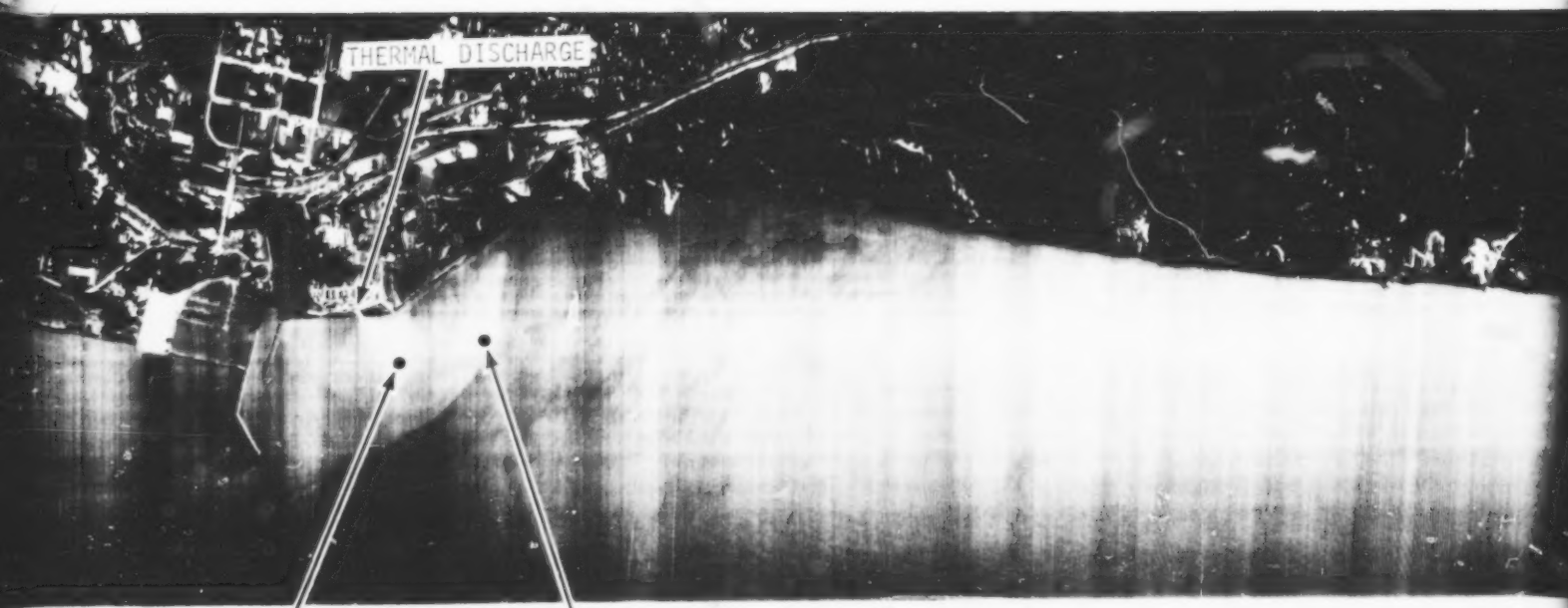
b) The plant's thermal plume is shown at the left end of Figure 10. It measured 2,490 feet into the Lake from shore and 3,250 feet in width (east-west).

c) There was a discontinuity recorded in the thermal plume, as indicated by the question mark in Figure 10. This point

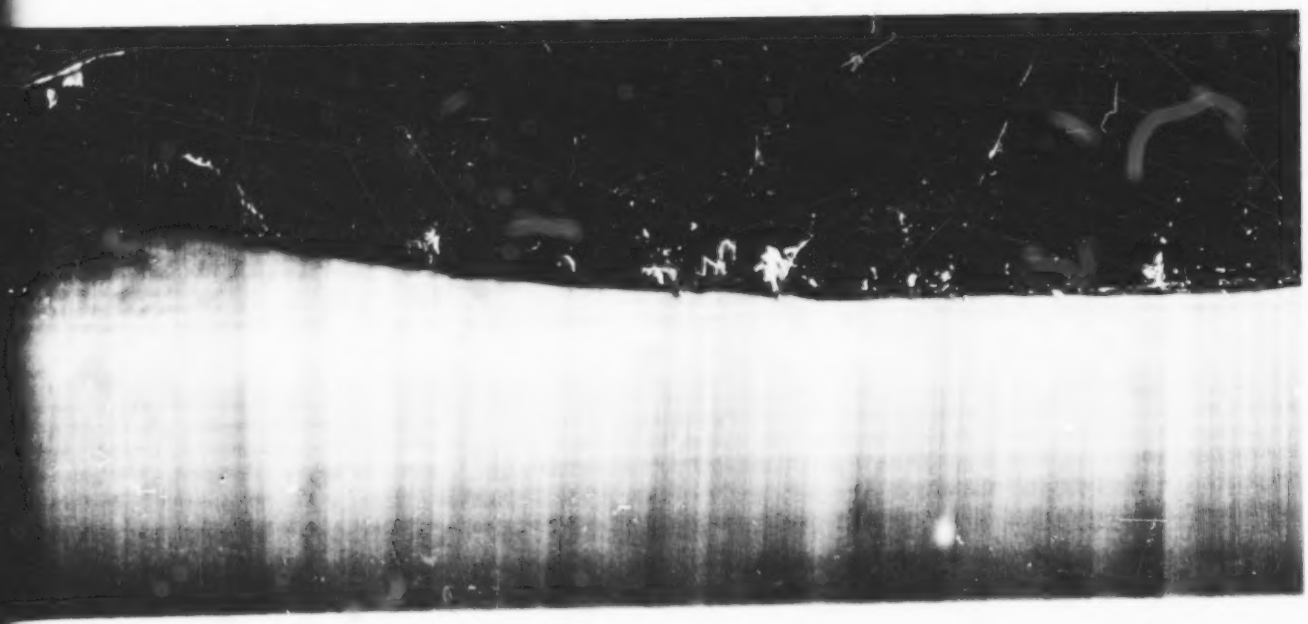
A



D



NORTHERN INDIANA PUBLIC SERVICE -
Michigan City Power Plan

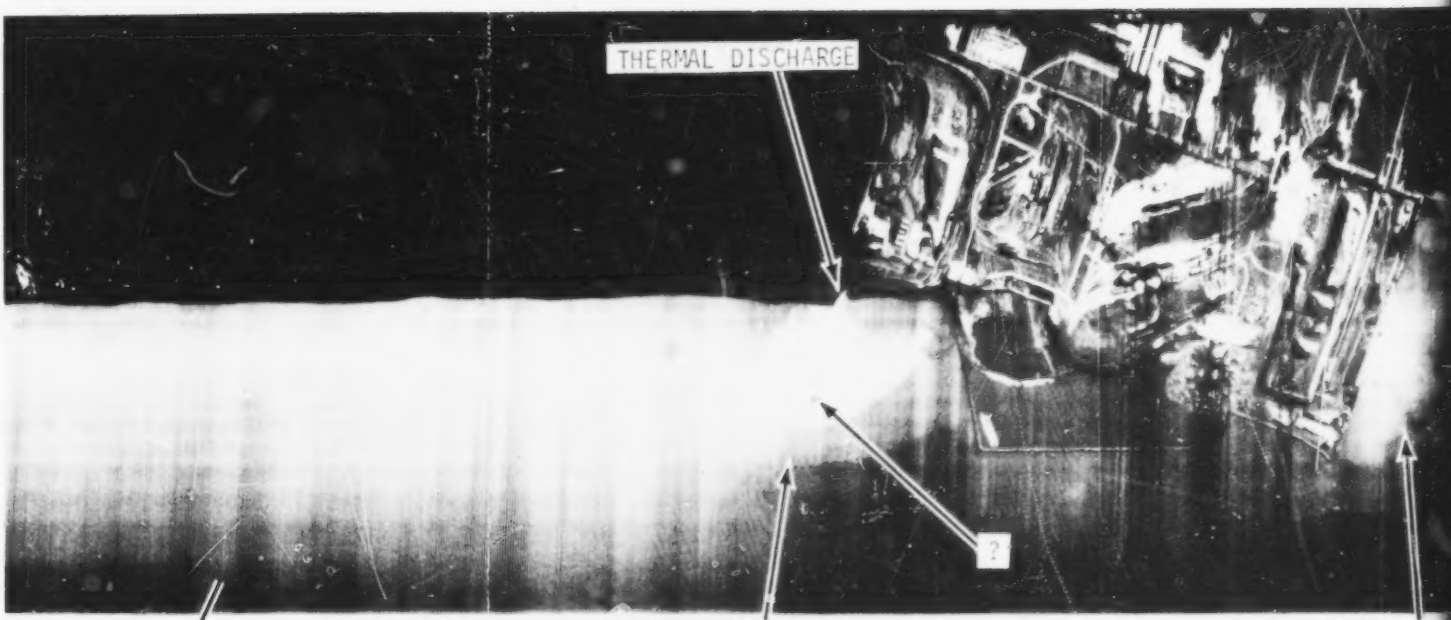


NORTHERN INDIANA PUBLIC SERVICE -
Michigan City Power Plant

FIGURE 9

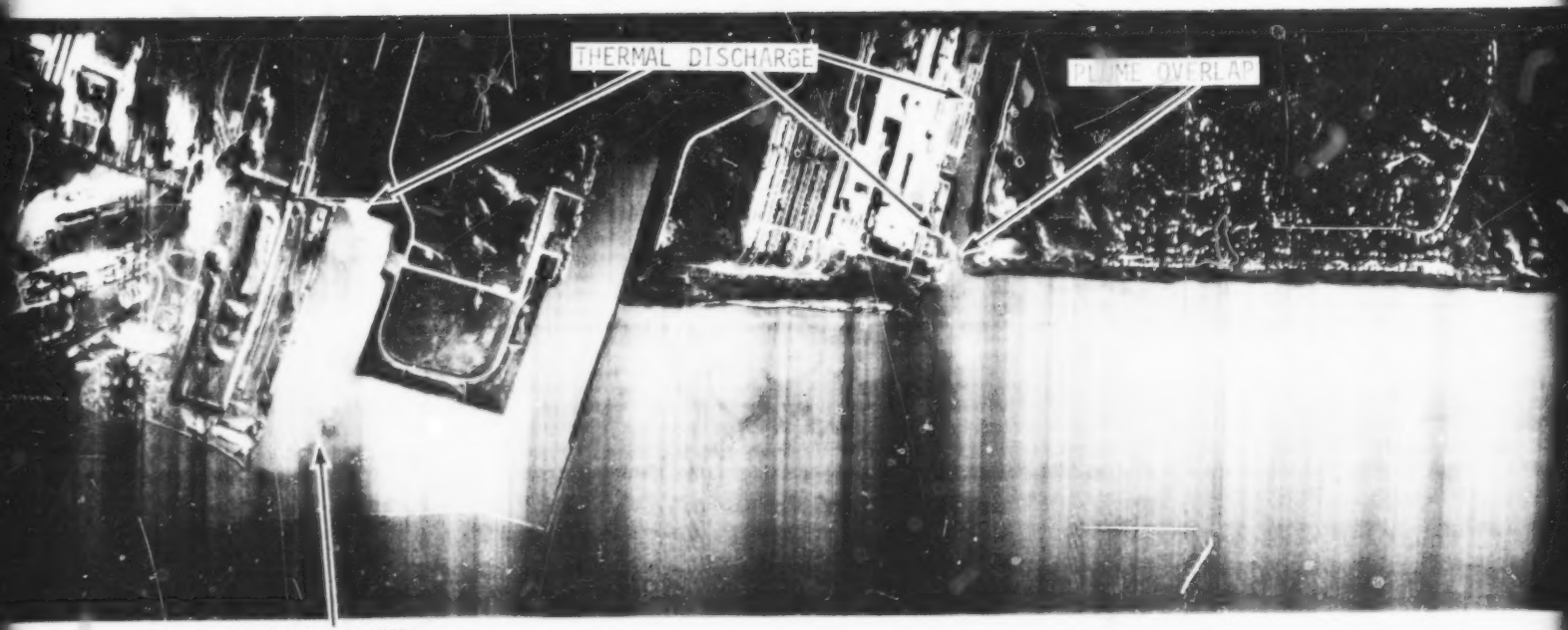
Reproduced from
best available copy.

A



NORTHERN [redacted] PUBLIC SERVICE -
Bailly Power Plant

B



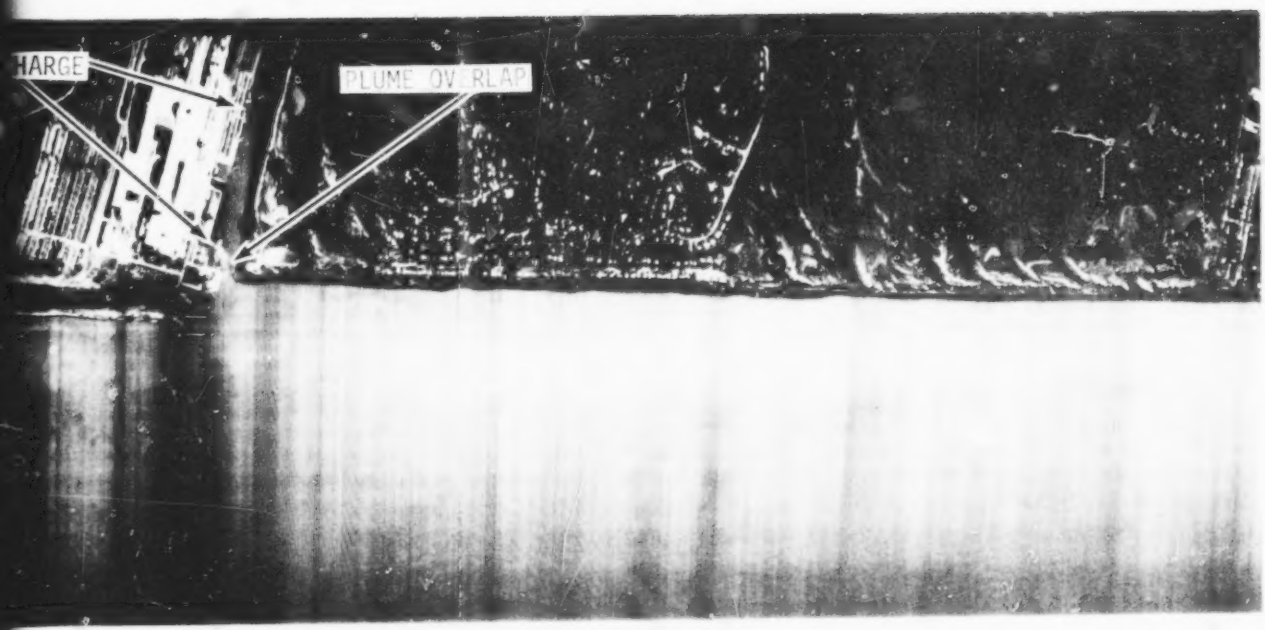


FIGURE 10

appeared at the same location, within the plume, in the thermal data from both aircraft.

d) The wind was from the west northwest at 3 to 8 mph.

4. Industrial Thermal Discharges

a) A total of three thermal discharges, reportedly from industrial sources, are indicated in the center of Figure 10. The two western-most thermal plumes, in the small canal, were overlapping at the time of flight.

b) A total of six thermal discharges, reportedly from industrial sources, are shown at the left and right ends of Figure 11. The three eastern-most discharges of the four identified on the left side, are from the facilities of the U. S. Steel Corporation. The source of the fourth is unknown. The source(s) of the two discharges, indicated on the right side of Figure 11, are unknown. In this immediate area, the two resultant plumes did overlap. Wind was from the west northwest at 3 to 8 mph.

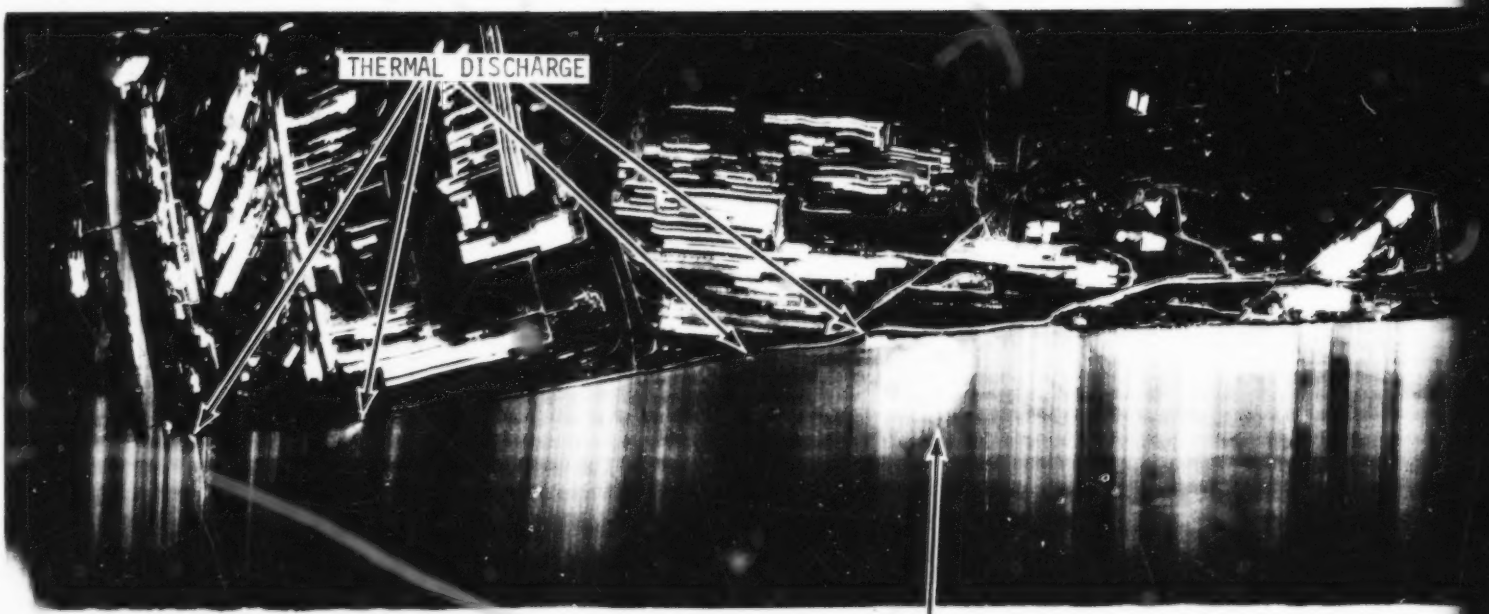
5. Northern Indiana Public Service - Mitchell Power Plant

a) The thermal discharge and the resultant thermal plume are shown in Figure 11. The plume measured 3,700 feet in length and 1,330 feet in width from the point of discharge out into Lake Michigan. The plume was dispersing in an easterly direction. Wind was from the west northwest at 3 to 8 mph.

6. Thermal Discharges - Union Carbide and American Oil Companies

a) The thermal discharges and the resultant thermal plumes, from

A

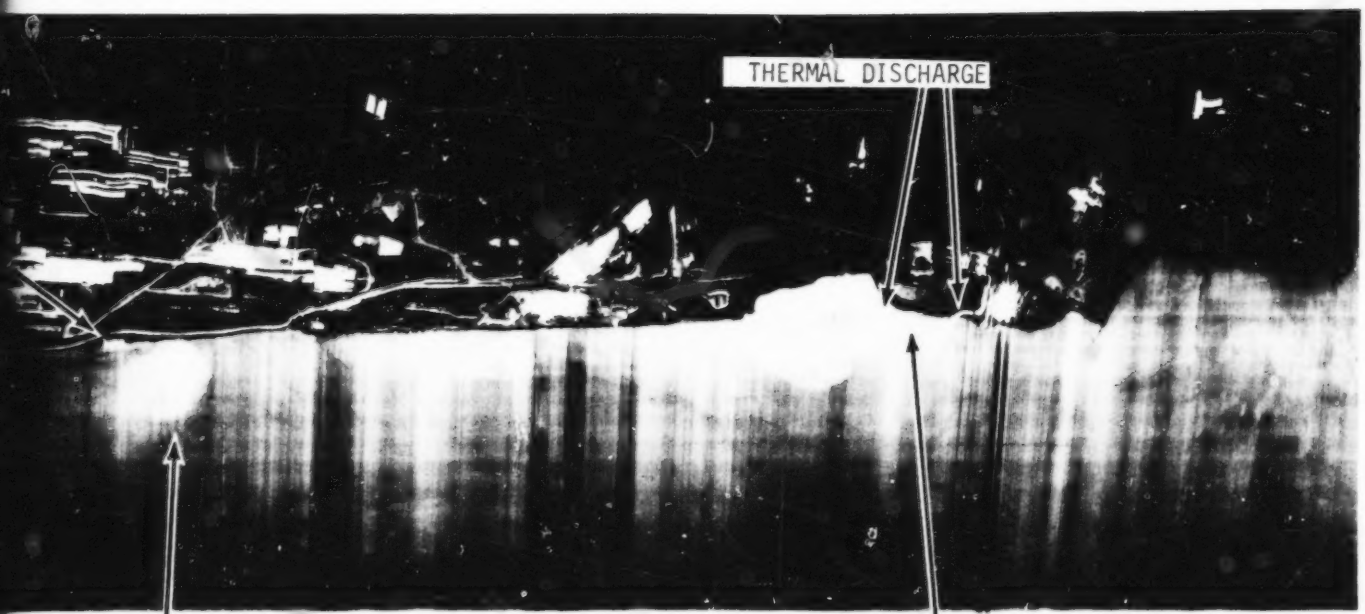


NORTH

NORTHERN INDIANA PUBLIC SERVICE -
Mitchell Power Plant

22

B



N INDIANA PUBLIC SERVICE -
Mitchell Power Plant

FIGURE 11

the facilities of the above-mentioned companies, are shown in Figure 12. The plumes were overlapping significantly in the area indicated. Wind was from the west northwest at 3 to 8 mph.

7. Thermal Discharges - Inland Steel and Youngstown Sheet and Tube Companies

   a) A total of five thermal discharges, which originated within the facilities of the above-mentioned companies, are shown in Figure 13. This is the Indiana Harbor area. As shown in Figure 13, there was significant plume overlapping in the lower reaches of the Harbor. Wind was from the west northwest at 3 to 8 mph.

   b) Along the far right edge of Figure 14, the warm water, seen flowing in an easterly direction, was from the combined thermal plumes [Figures 13 and 14] entering Lake Michigan.

8. Commonwealth Edison - State Line Power Plant

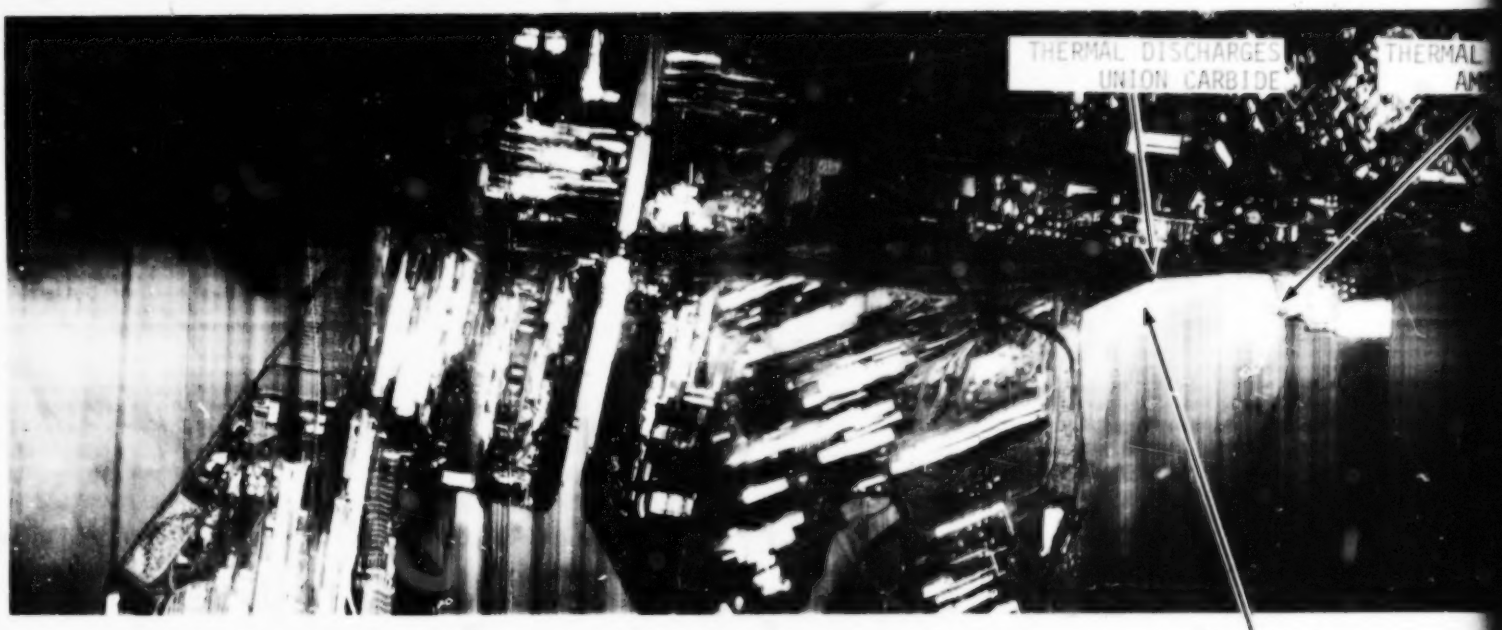
   This discharge was not recorded due to cloud cover in the area.

9. Industrial Thermal Discharges

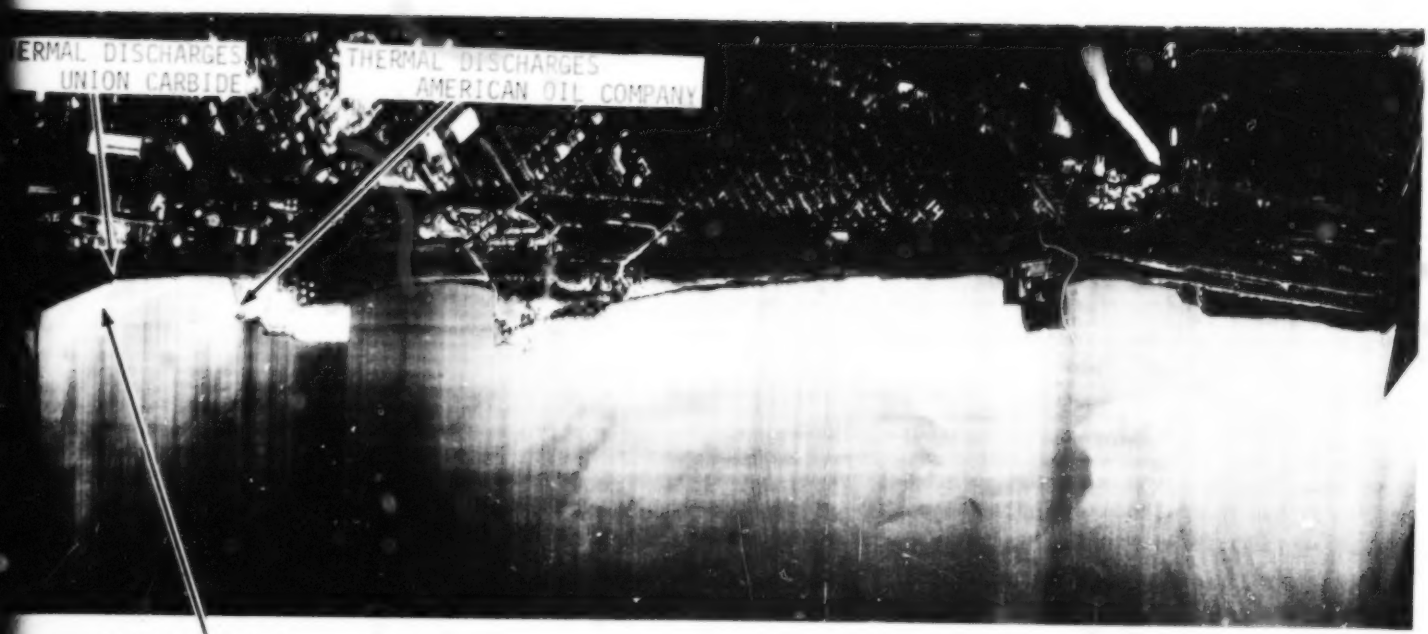
   a) A total of five thermal discharges were recorded in the area depicted in Figure 14. There are two small discharges indicated by the long arrow in the 8 o'clock position. The areas of thermal plume overlapping are also indicated.

   The combined plumes were dispersing in an easterly direction. The wind was from the west northwest at 3 to 8 mph.

A


THERMAL DISCHARGES
UNION CARBIDE
THERMAL
AM
PLUME OVERLAP
NORTH

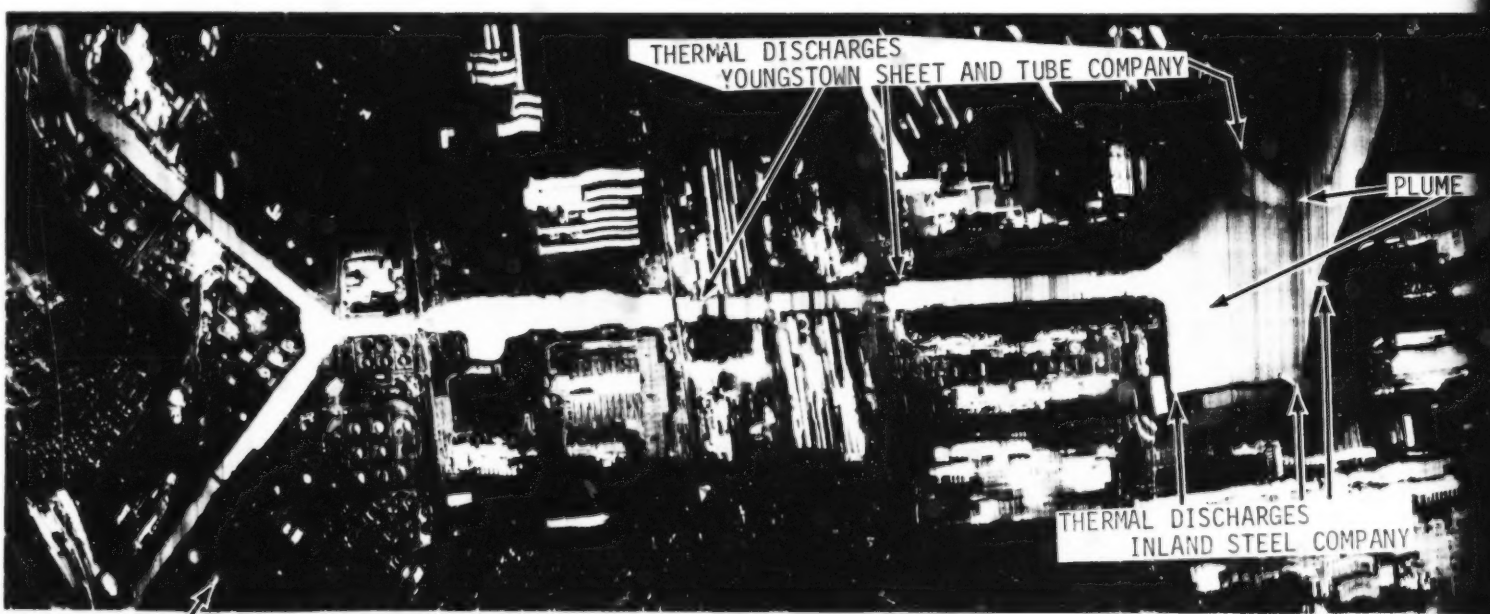
B



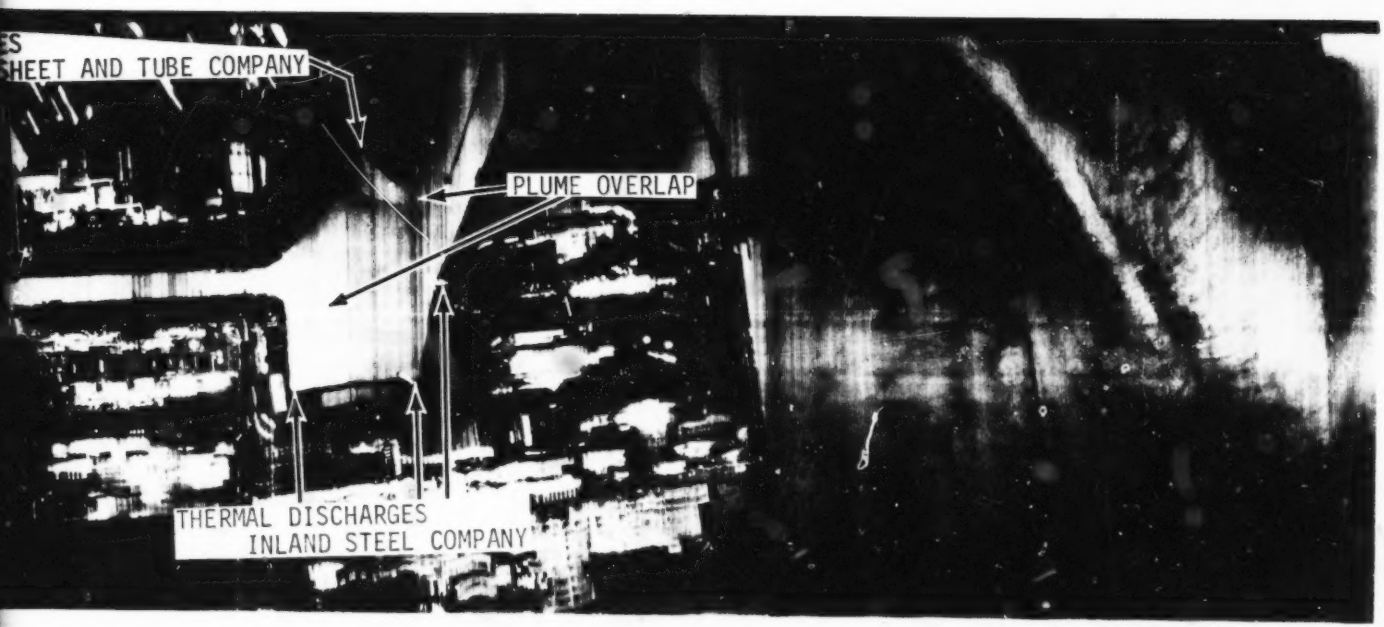
Industrial Thermal Discharges

FIGURE 12

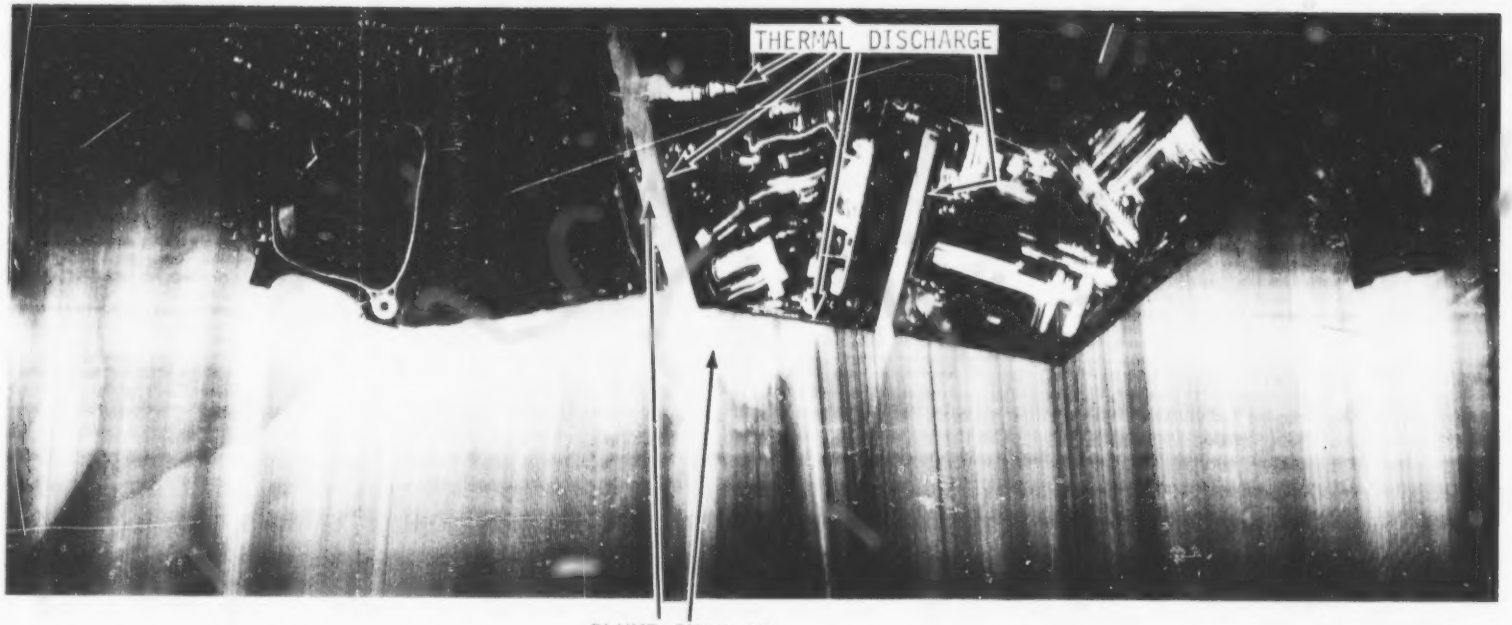
A


THERMAL DISCHARGES
YOUNGSTOWN SHEET AND TUBE COMPANY
PLUME
THERMAL DISCHARGES
INLAND STEEL COMPANY
NORTH

B



Industrial Thermal Discharges FIGURE 13



Industrial Thermal Discharges FIGURE 14

10. Industrial Thermal Discharges

a) Three industrial thermal discharges and the resultant thermal plumes are shown in the left center of Figure 15. There was no apparent surface plume overlapping in this area. The plumes were dispersing in a southerly direction. Wind was from the west northwest at 3 to 8 mph. The northern most discharge, of the three, reportedly originates within the U. S. Steel Corp., Waukegan Plant.

11. Commonwealth Edison - Waukegan Power Plant

a) The temperature of the discharge water, at the mouth of the plant's canal, was 64.4°F as provided by ground truth.

b) The surface temperature of the background waters of Lake Michigan was 46.4°F as provided by ground truth. This value was measured at a point approximately 1,400 feet north of the canal and 400 feet into the water from shore.

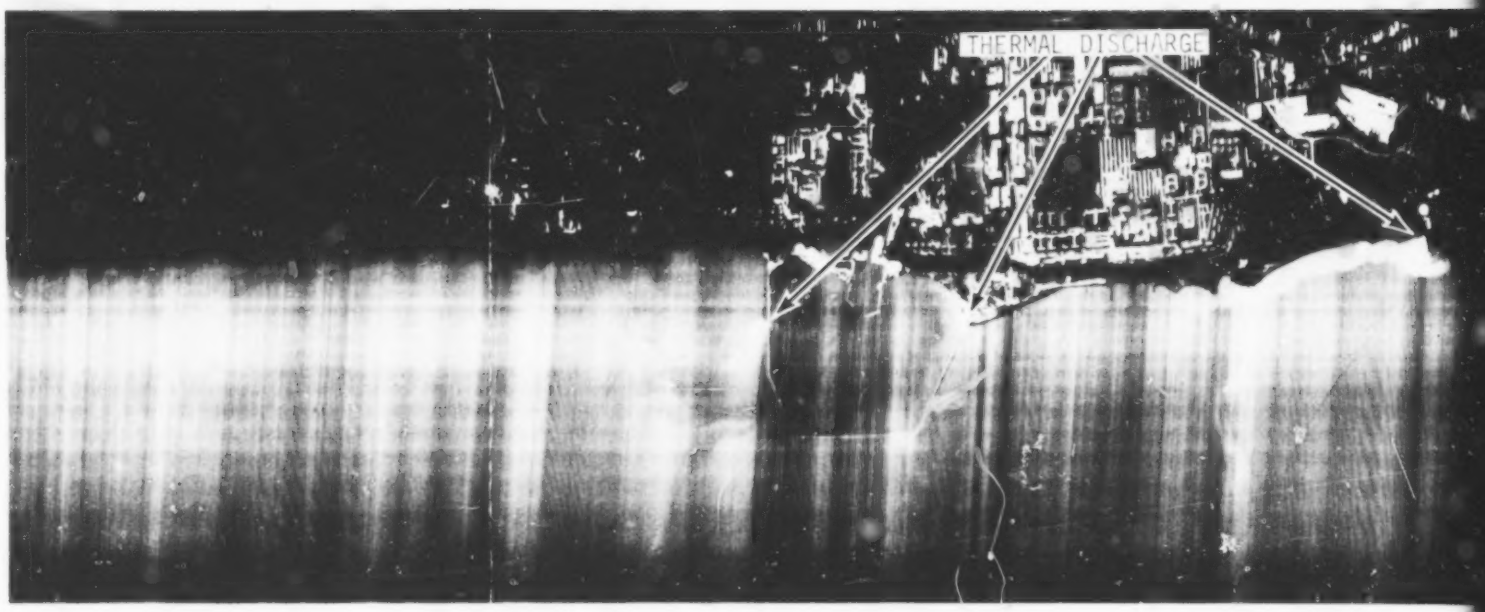
c) The thermal plume is shown in Figure 15. The surface temperature of the plume, at the 1,000 feet and 2,000 feet points shown in Figure 15, was 62.5°F and 49.8°F respectively. The temperature increase of the surface water within the plume, at the above mentioned paints, was 16.1°F and 3.4°F respectively.

d) The wind was from the west northwest at 5 mph.

e) There was a thermal discharge located approximately 4,140 feet south along shore from the power plant discharge as indicated in Figure 15. The identity of the source of the thermal discharge is unknown. There was significant overlapping of this plume with the power plant's plume as indicated.

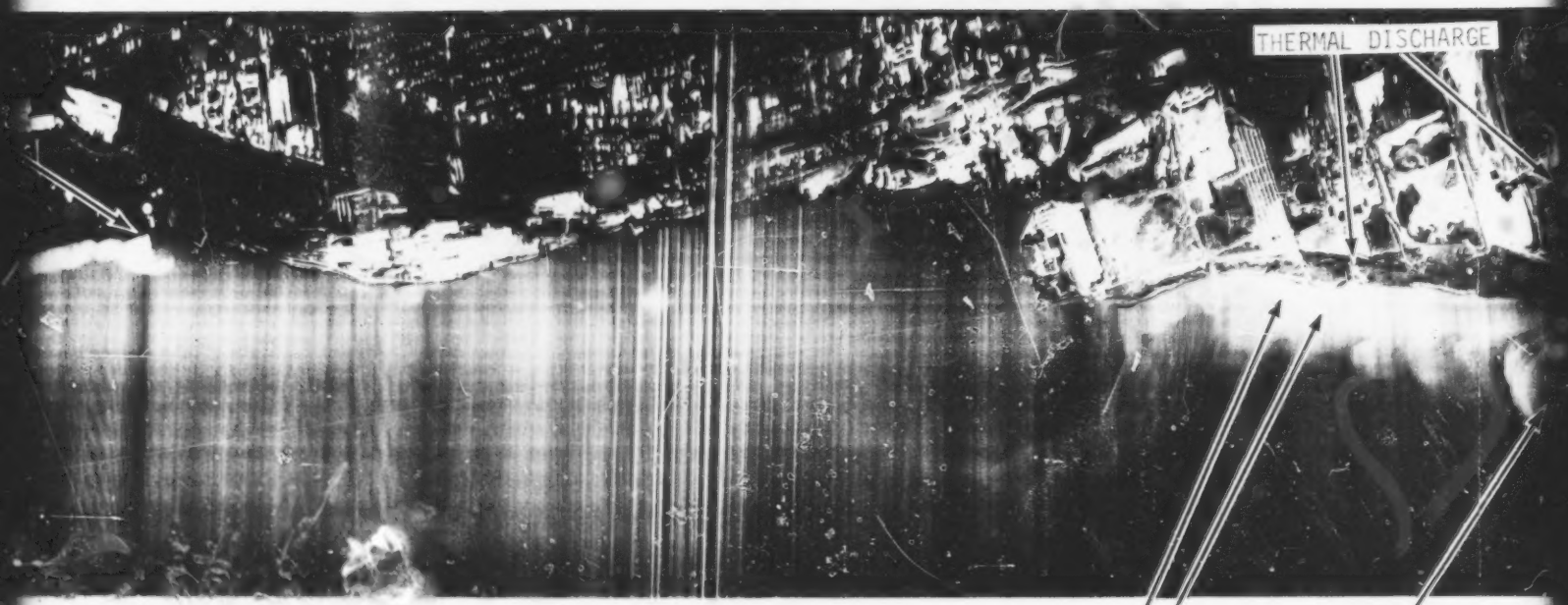
NOTE: The respective locations of the industrial thermal maps are given in Figure 16.

A

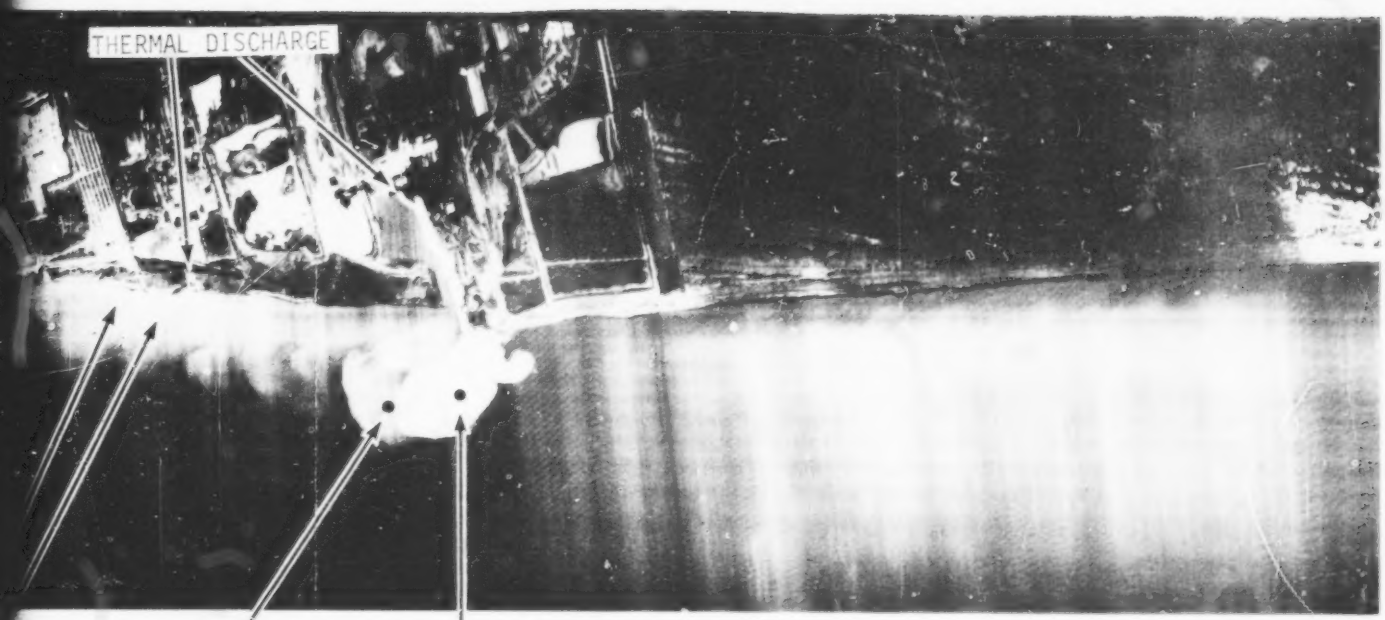


NORTH

B



8



COMMONWEALTH EDISON -
Waukegan Power Plant

A

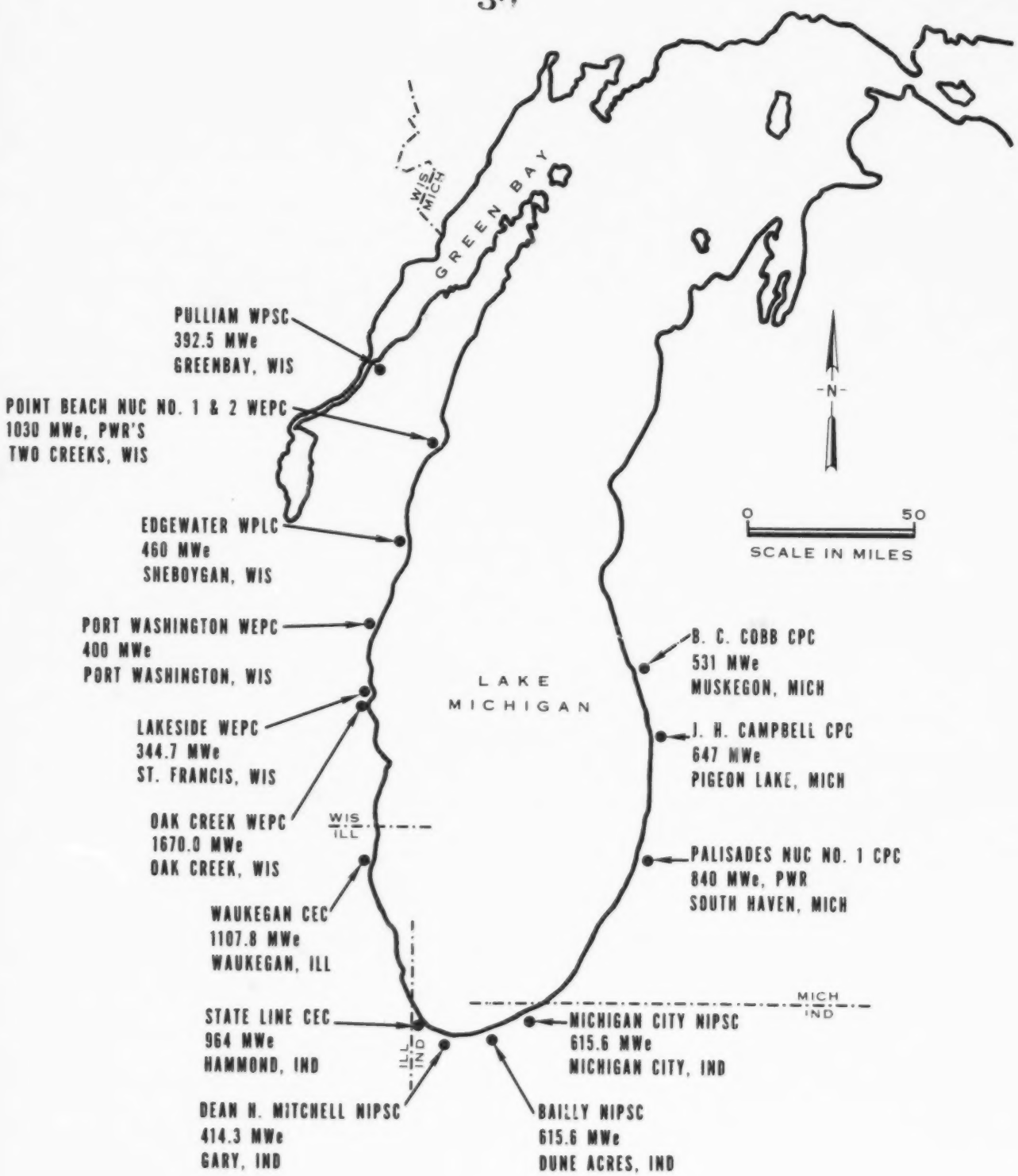
FIGURE 14
FIGURE 6
FIGURE 12
FIGURE 4
FIGURE 5
FIGURE 13
FIGURE 2
FIGURE 10
FIGURE 3
FIGURE 11
CHICAGO
EAST CHICAGO
GARY
HAMMOND
LAKE MICH
COOK COUNTY
LAKE COUNTY
INDIANA
ILLINOIS
MICHIGAN
COOK COUNTY
BERRIEN COUNTY
Belmont Harbor
Chicago Harbor
Calumet Harbor
Whiting
Cicero
Oak Lawn
Evergreen Park
Blue Island
Riverdale
Dolton
Harvey
Phoenix
Markham
South Holland
Hazel Crest
Homewood
Flossmoor
Chicago Heights
Park Forest
Steger
Matteson
Lansing
Munster
Highland
Griffith
Hobart
Schererville
Black Oak
East Gary
Portage
Burnham
Calumet City
Slag dump
Substation

B
87°00'
LAKE MICHIGAN
COOK COUNTY
BERRIEN COUNTY
ILLINOIS
MICHIGAN
INDIANA
BERRIEN COUNTY
PORTER COUNTY
FIGURE 1
FIGURE 9
FIGURE 2
FIGURE 10
FIGURE 3
FIGURE 11
FIGURE 5
FIGURE 13
MICHIGAN CITY
GARY
Michiana Shores (MICH)
Michiana Shores IND
Beverly Shores
Dune Acres
Porter
Chesterton
East Gary
Portage
Hobart
Valparaiso
Bodin
Long Beach
Grand Beach
Substation
Municipal
Orthopaedic
Underground Pipeline
FIGURE 16
THERMAL MAP

CHICAGO

FIGURE 16

THERMAL MAP TRACE



LOCATION MAP LAKE MICHIGAN ELECTRIC POWER GENERATION STATIONS